SOCIO-ECONOMIC IMPACT OF 5G TECHNOLOGIES

A thesis submitted to the
School of Business and Social Sciences
Department of Business Development and Technology
Aarhus University

In the partial fulfilment of requirements for the

DOCTOR OF PHILOSOPHY

SOLIDUM PETIT IN PROFUNDIS · UNIVERSITAS ARHUSIENSIS ·

May 2018

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BRIEF CV

Sriganesh Rao received his B.E (Electronics) degree from Bangalore University (India) in 1980 and MTech (Electronics) degree from Karnataka Regional Engineering College (Now renamed as National Institute of Technology, Surathkal) of Mysore University, in 1983 followed by MBA (Technology Management) of Deakin University, Australia in 2000 with focus on International Telecommunication Management.

He is an ICT Professional with over 34 years of global experience in leading complex technology projects in Australia and India, with rich background in Business Development, Engineering, Program Management and QA in Telecom, Government & Defence verticals across Embedded, Engineering Services, Testing and Manufacturing horizontals.

His experience spans across leading IT organizations like Tata Consultancy Services & IBM, Telecom Service Providers like TATA Teleservices & C&W OPTUS (Australia), Telecom OEMs like Bharat Electronics, United Telecoms & ERG (Australia) and Telecom OSS/ BSS Providers like Alopa Networks. At present, he is with Tata Consultancy Services, Bangalore (India) working in Telecom domain. He has handled Business development and Pre-sales Solutioning in Telecom, Media & Entertainment, Government, Defence & Aerospace market segments and led strategic initiatives in new technology areas –IPv6 and M2M/ IoT for India business.

He is a Senior Member of IEEE, Senior Member and Certified Professional of Australian Computer Society and Life Member of Computer Society of India. He is actively involved in M2M/ IoT related initiatives of Professional bodies like IEEE, GISFI, TM Forum, ACS and TiE. As the Chairman for the Dept. of Telecom’s (Govt of India) “M2M Gateway and Architecture" Workgroup, he has contributed to the preparation of “National Telecom M2M Roadmap”. Currently, he is Member of the National Working Group -20 on the subject of “IoT and its applications in Smart Cities and Communities”

His current interests include 5G, M2M, IoT, Smart Cities, Industries 4.0 and Business Model Innovation.

DANSK RESUME

Sriganesh Rao modtog sin BE (Electronics) grad fra Bangalore University (Indien) i 1980 og MTech (Electronics) grad fra Karnataka Regional Engineering College (nu omdøbt som National Institute of Technology, Surathkal) af Mysore University i 1983 efterfulgt af MBA (Technology Management) i Deakin University, Australien i 2000 med fokus på International Telecommunication Management.

Han er en ikt-professionel med over 34 års global erfaring inden for førende komplekse teknologiprojekter i Australien og Indien med en rig baggrund i Business Development, Engineering, Program Management og QA inden for Telecom, Government & Defense verticals på tværs af Embedded, Engineering Services, Testing og Fremstilling horisontaler.

Hans erfaring spænder over førende it-organisationer som Tata Consultancy Services og IBM, Telecom Service Providers som TATA Teleservices & C & W OPTUS (Australien), Telecom OEM'er som Bharat Electronics, United Telecom & ERG (Australien) og Telecom OSS / BSS Providers som Alopa Networks. I øjeblikket er han hos Tata Consultancy Services, Bangalore (Indien), der arbejder i Telecom-domænet. Han har håndteret Business Development og Pre-Sales Solutioning inden for Telecom, Media & Entertainment, Government, Defense & Aerospace markedssegmenter og ledede også strategiske initiativer inden for nye teknologier -IPv6 og M2M / IoT til Indien business.

Han er senior medlem af IEEE, Senior Member og Certified Professional of Australian Computer Society og Life Member of Computer Society of India. Han er aktivt involveret i M2M / IoT-relaterede initiativer af professionelle organer som IEEE, GISFI, TM Forum, ACS og TiE. Som formand for Telegomsdepartementets (Govt of India) "M2M Gateway and Architecture" arbejdsgruppe har han bidraget til forberedelsen af "National Telecom M2M Roadmap". I øjeblikket er han medlem af den nationale arbejdsgruppe -20 på emnet "IoT og dets applikationer i Smart Cities and Communities"

Hans nuværende interesser omfatter 5G, M2M, IoT, Smart Cities, Industries 4.0 og Business Model Innovation..

Abstract

Internet of things started proliferating post 2012, even though the term was coined in 1999. This was due to the explosion of internet address availability enabled by IPv6. There was expectation of an avalanche of traffic caused by the explosion of the number of connected devices which could create a huge diversity of requirements and use cases. The wirelessly connected IoT had the potential to bring in huge benefits to society and businesses and communication networks needed to support this. METIS, a consortium of global industries and telecom operators, started to define such a communication network in 2012 and laid the foundation to 5G, the next generation mobile and wireless communication system.

The author, being a Business Development & ICT Technology professional, conceived the idea of researching the global impact that 5G would have on society and businesses. He wanted to explore disruptive applications and use cases in all domains, enabled by 5G. He started working on this during end of 2013, when 5G feature definitions and standardization was still in its infancy. The purpose of the research was to act as a guide for Business and Government leaders, to consider the reach and scope of impact, so that they could take adequate measures to handle them. Author's professional global experience of around 35 years in ICT industries and a very good understanding of market, has contributed immensely to this research by being able to bring in his original thoughts and ideas.

The potential scope and economic impact due to 5G, has been researched along with impact on how people live and work. Domains, which would potentially be impacted by 5G, have been identified and the impact thereof have been researched. The domains researched includes Healthcare, Industries 4.0, Transport Systems, Smart Cities, Energy systems, Education, Home & Living, Security & Surveillance, Retail business, Telecom & Content Service Providers, and IoT/M2M System integrators. The global trends happening in these domains were studied. In each of these domains, the consumer behaviour, business objectives and the regulatory requirements have been analysed to create demand drivers for that domain. The current communication technologies were analysed for their suitability to meet those market demands. The features of 5G, meeting those market drivers were discussed. Detailed analysis has been made on the social and the economic impact that 5G connectivity could bring into these domains. The potential disruption in job market is analysed with recommendation of addressing them. Applications and Use Cases, harnessing the full potential of 5G, have been identified and listed in all domains. New business models and changes in exiting business models in all domains, have been discussed.

The author has discussed the challenges that could be faced in 5G implementation and the policy recommendations for governments to overcome these challenges. This would ensure successful 5G deployments and enable the application and use cases identified in this thesis. Future research directions have been listed.

Abstrakt

Internettet af ting begyndte at sprede efter 2012, selvom begrebet blev mønstret i 1999. Dette skyldtes eksplosionen af internetadresse tilgængelighed aktiveret af IPv6. Der var forventning om en lavine af trafik forårsaget af eksplosionen af antallet af tilsluttede enheder, som kunne skabe en stor mangfoldighed af krav og brugssager. Den trådløst forbundne IoT havde potentialet til at bringe store fordele til samfundet og virksomheder og kommunikationsnetværk, der var nødvendige for at understøtte dette. METIS, et konsortium af globale industrier og teleoperatører, begyndte at definere et sådant kommunikationsnet i 2012 og lagde grunden til 5G, det næste generation mobil og trådløst kommunikationssystem.

Forfatteren, som er en erhvervsudviklings- og IKT-teknologi, har ideen om at undersøge den globale indvirkning, som 5G ville have på samfundet og virksomhederne. Han ønskede at udforske forstyrrende applikationer og bruge sager på alle områder, aktiveret af 5G. Han begyndte at arbejde på dette i slutningen af 2013, da 5G-funktional definitioner og standardisering stadig var i sin barndom. Formålet med forskningen var at fungere som vejledning for erhvervs- og regeringsledere, for at overveje omfangets rækkevidde og omfang, således at de kunne træffe passende foranstaltninger til at håndtere dem. Forfatterens professionelle globale erfaring med omkring 35 år i it-industri og en meget god forståelse for markedet har bidraget enormt til denne forskning ved at kunne indhente sine oprindelige tanker og ideer.

Det potentielle omfang og den økonomiske virkning på grund af 5G er blevet undersøgt sammen med indflydelse på, hvordan folk bor og arbejder. Domæner, som potentielt kunne påvirkes af 5G, er blevet identificeret, og virkningen heraf er blevet undersøgt. De undersøgte domæner omfatter Healthcare, Industries 4.0, Transportsystemer, Smart Cities, Energisystemer, Uddannelse, Home & Living, Sikkerhed og Overvågning, Detailvirksomheder, Telecom & Content Service Providers og IoT / M2M System Integrators. De globale tendenser i disse domæner blev undersøgt. I hvert af disse domæner er forbrugeradfærd, forretningsmål og lovkrav blevet analyseret for at skabe efterspørgselsdrivere for det pågældende domæne. De nuværende kommunikationsteknologier blev analyseret for deres egnethed til at imødekomme disse markedskrav. Funktionerne ved 5G, der mødtes med disse markedsdrivere, blev diskuteret. Der er udført en detaljeret analyse af de sociale og økonomiske konsekvenser, som 5G-konnektivitet kan bringe ind i disse domæner. Den potentielle forstyrrelse på arbejdsmarkedet analyseres med henstilling om at adressere dem. Applikationer og brugssager, der udnytter 5G's fulde potentiale, er blevet identificeret og opført på alle områder. Nye forretningsmodeller og ændringer i spændende forretningsmodeller på alle områder er blevet diskuteret.

Forfatteren har diskuteret de udfordringer, der kunne konfronteres med 5G implementering og de politiske anbefalinger for regeringer at overvinde disse udfordringer. Dette ville sikre succesfulde 5G-implementeringer og aktivere applikationen og bruge sager identificeret i denne afhandling. Fremtidige forskningsvejledninger er blevet opført.

Acknowledgment

My inspiration to work in area of analysing Global socio-economic impact of 5G technologies, has been primarily due to the opportunity of meeting Prof Ramjee Prasad at a GISFI meeting at Bangalore during end of 2012. During that time, I was handling a new IPv6 Business group formed at Tata Consultancy Services and was looking at various new Business opportunities and applications that would emerge, enabled by IPv6. Tata Consultancy Services Ltd was a Member company of GISFI, which was chaired by Prof Ramjee Prasad, and was working in IoT architecture workgroup of GISFI. I attended a GISFI standardization meeting held at Bangalore, to understand IoT in greater detail, so that I could plan applications enabled by this and look at new Business opportunities for TCS. I was introduced to Prof Prasad and I was greatly impressed by his deep knowledge and discussed my interest with him. He initiated me to 5G, that it would be a broader area which could see emergence of new Businesses and new Business Models. I expressed my desire to work with him in this area and he kindly agreed to take me as his PhD student. My interaction with Prof. Ramjee Prasad initiated during this time and since then he has been a prime motivator, mentor, and guide for me to pursue this research. I express my sincere gratitude to Prof. Ramjee Prasad.

In addition to this, I would also like to thank Prof Peter Lindgren, Director of CGC Herning, for his valuable inputs and guidance in Business Model Innovation. My profound thanks to Dr Ambuj Kumar, Postdoc, Department of Business Development and Technology, Aarhus University for his help and guidance during my stay at the University. I would like thank Dr Vandana Rohokale, SITS, Pune for her valuable guidance through my thesis completion.

Last but not the least; I thank my family for their full-hearted support and understanding for enabling me to complete this research work.

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3G PP	3rd Generation Partnership Project
5G	5th Generation Mobile systems
5G NG	5th Generation New Radio
5G PPP	5G Infrastructure Public Private Partnership
ACS	Australian Computer Society
ADM	Application Development and Maintenance
AMI	Advanced Metering Infrastructure
APAC	Asia Pacific
AR	Augmented Reality
ARIB	Association of Radio Industries and Business
ARPU	Average Revenue Per User
B2B	Business to Business
B2C	Business to Consumer
BAN	Body Area Network
BM	Business Model
BMI	Business Model Innovation
BSNL	Bharat Sanchar Nigam Ltd
BSS	Business Support System
C&W	Cable & Wireless
CAGR	Compounded Annual Growth Rate
CAPEX	Capital Expenditure
CAV	Connected and Autonomous Vehicles
CCTV	Closed Circuit Tele Vision
CGC	CTIF Global Capsule
CIS	Clinical Information Systems
CO2	Carbon Di-Oxide
CPS	Cyber Physical Systems
CSP	Communication Service Provider
CT	Computed Tomography
D2D	Device to Device
DSL	Digital Subscriber Line
ECG	Electro Cardio graph
EHR	Electronic Health Records

eMBB	Enhanced Mobile Broadband
EMR	Electronic Medical Record
ETSI	European Telecommunications Standards Institute
EU	European Union
EV	Electric Vehicles
FMCG	Fast Moving Consumer Goods
FWA	Fixed Wireless Access
GBPS	Giga Bits Per Second
GDP	Gross Domestic Product
GISFI	Global Standardization Forum of India
GSM	Global System for Mobiles
GST	Goods and Services Tax
HD	High Definition
HFC	Hybrid Fibre Co-axial
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communication Technologies
IEEE	Institute of Electrical and Electronics Engineers
IEEE-SA	IEEE- Standards Association
IIOT	Industrial Internet of Things
IMT 2020	International Mobile Telecommunication for 5G
IoMT	Internet of Medical Things
IOT	Internet of Things
IP	Internet Protocol
IPv6	Internet Protocol Version 6
ISP	Internet Service Provider
ISTE	International Society for Technical Education
ITS	Intelligent Transport System
ITU-R	International Telecommunication Union – Radio communication
ITU-T	International Telecommunication Union – Telecommunication
IVR	Interactive Voice Response
LTE	Long Term Evolution
M2M	Machine to Machine
Mbps	Megabits per second
MEMS	Micro Electro Mechanical System
METIS	Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society.

MIMO	Massive Input Massive Output
MNO	Mobile Network Operator
MOOC	Massive Open Online Courses
mS	Milli Seconds
MSOs	Multi Service Operators
MTC	Machine Type Communications
MVNO	Mobile Virtual Network Operator
NFC	Network Function Virtualization
NFV	Network Function Virtualization
NICT	National Institute of Information and Communication, Japan
NIST	National Institute of Standards and Technology
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
OSS	Operational Support System
OTA	Over The Air
OTT	Over The Top
PHR	Personal Health Records
PPP	Public Private Partnership
PSTN	Public Switched Telephone Network
PV	Photo Voltaic
RFID	Radio Frequency Interface Device
SaaS	Software as a Service
SDN	Software Defined Networking
SDN	Software Defined Network
SI	System Integrator
SIM	Subscriber Interface Module
SLA	Service Level Agreement
SMEs	Small and Medium Enterprises
SMS	Short Messaging Service
STB	Set Top Box
TCS	Tata Consultancy Services
ToD	Time of Day
ToU	Time of Use
TSDSI	Telecommunications Standards Development Society of India
TSP	Telecommunication Service Provider

UAV	Unmanned Aerial Vehicles
UHD	Ultra-High Definition
UMTS	Universal Mobile Telecommunication Systems
URV	Unmanned Road Vehicles
USD	United State Dollar
V2I	Vehicle to Infrastructure
V2N	Vehicles to Network
V2V	Vehicle to Vehicle
V2X	Vehicles to Everything
VNO	Virtual Network Operator
VoIP	Voice Over Internet Protocol
VR	Virtual Reality
VRU	Vulnerable Road User
WHO	World Health Organisation
WiFi	Wireless Fidelity
WISDOM	Wireless Innovative System for Dynamic Operating Mega Communication

1.0 Introduction

1.1 Research Problem

Important technologies, that have the greatest potential to drive substantial economic impact and disruption by 2025, can come in any field or emerge from any scientific discipline, but they share four characteristics explained below. It is very important to identify the potential impacts of disruptive technologies. Technology can be viewed both in terms of potential economic impact and capacity to disrupt, since these effects go together and because both are of critical importance to leaders.

1. High rate of technology change.

   Technology is rapidly advancing or experiencing breakthroughs. Disruptive technologies typically demonstrate a rapid rate of change in capabilities in terms of price/ performance relative to substitutes and alternative approaches, or they experience breakthroughs that drive accelerated rates of change or discontinuous capability improvements.

2. Broad potential scope of impact

   The potential scope of impact is broad. To be economically disruptive, a technology must have broad reach—touching companies and industries and affecting (or giving rise to) a wide range of machines, products, or services

3. Large economic value that could be affected

   Significant economic value could be affected. An economically disruptive technology must have the potential to create massive economic impact. The value at stake must be large in terms of profit pools that might be disrupted, and capital investments that might be rendered obsolete.

4. Substantial potential for disruptive social impact.

   Technologies that matter have the potential to disrupt social life. They can transform how people live and work. They can bring in conveniences which were earlier unthinkable. They can bring in rapid obsolescence to people's skills in the job market or create entirely new opportunities. This could potentially impact the social fabric of a nation.

It is important to identify technologies that have potential to affect billions of consumers, hundreds of millions of workers, and trillions of dollars of economic activity across industries. Business and Government leaders need to understand how the competitive advantages on which their strategies have been based, might erode or be enhanced a decade from now by emerging technologies—how technologies might bring them new customers or force them to defend their existing bases or inspire them to invent new strategies.

Policy makers and societies need to prepare for future technology, too. To do this well, they will need a clear understanding of how technology might shape the global economy and society over the coming decade. They will need to decide how to invest in new forms of education and infrastructure and figure out how disruptive economic change will affect comparative advantages. Governments will need to create an environment in which citizens can continue to prosper, even as emerging technologies disrupt their lives. Lawmakers and regulators will be challenged to learn how to manage new biological capabilities and protect the rights and privacy of citizens.

Many forces can bring about large-scale changes in economies and societies— demographic shifts, labour force expansion, urbanization, or new patterns in capital formation, for example. But since the Industrial Revolution of the late 18th and early 19th centuries, technology has had a unique role in powering growth and transforming economies. Technology represents new ways of doing things, and once mastered, creates lasting change, which businesses and cultures do not "unlearn." Adopted technology becomes embodied in capital, whether physical or human, and it allows economies to create more value with less input. At the same time, technology often disrupts, supplanting older ways of doing things and rendering old skills and organizational approaches irrelevant.

1.2 Objectives of my PhD Research

The broad objective of the research is to identify disruptive technologies and explore the transformational capacities of them. The detailed objective of the PhD study is to address social, policy, technological and environmental issues pertinent to the 5G Technologies including Internet of Things, M2M and Mobile Internet. The goal is to track 5G Technologies based on top market opportunities and challenges that will address global, political, and environmental issues. The study will also address topics that aim to improve the lives of citizens in broad areas such as health, education, innovation, transportation, job creation, reliable utilities, safety, and security.

The objective of the research is to identify all the areas which will potentially be impacted by the transformational features of 5G through qualitative analysis and then explore the global trend happening in these areas. Further, the market demands in each of these domains are listed by analysing the consumer behaviour, business drivers and the regulatory requirements in those domains. The current communication technologies are studied for their ability to meet these market demands. Further, analysis is to be made as to how these requirements can be addressed by the proposed features of 5G. The objective also involves a qualitative analysis of the social and economic impact of the 5G enabled services in all the identified impacted domains, and to study how the new services enabled by 5G Technologies will impact the nature of work and the skills needed to be acquired by the masses to harness the benefits of these technologies. The current business models in the above domains would be discussed and improvements or innovations required to harness the capabilities enabled by 5G technologies, would be presented.

1.3 Contributions and Novelties

The research encompassed all domains of life, as given below, which could potentially be impacted by 5G technologies. The author has explored the global trends in each of the above domains and analysed the market drivers of them. The market drivers include the demands by the Consumers i.e. the entities using those services or being affected by those services, the entities providing those services and any government regulations, as applicable. The author has also tracked the current state of global deployment of 5G.

The communication requirements for these services are derived from the market demands and limitations in the current communication methodologies, if any, are highlighted. Further, analysis is made as to how these requirements can be addressed by the proposed features of 5G. The social and economic impact of the 5G enabled services in all the above domains are discussed.

Finally, the current business models in the above industries are studied and the innovation required in their Business Models, to harness the capabilities enabled by 5G technologies, are presented.

The domains researched are:

- Industries 4.0, which is the new evolution of Industries, which brings in robotic assisted manufacturing and complete automation.
- Telecommunication technology providers or Telecom Operators, who provide the complete backbone connectivity, enabling delivery and operation of innovative services across all domains.
- Smart Cities, which are the engine for socio-economic growth of societies providing a 'Integrated Vision" and exceptionally good co-ordination amongst various multi-stakeholders in the Smart City eco-system, enabled by connectivity.
- Health care industry, which could see lot of innovation in the services enabled by 5G
- Intelligent Transport Systems, and Automotive industry including connected vehicles, autonomous vehicles, and unmanned air vehicles.
- Smart Energy, which can improve quality of service, prevent outages, control the stability of the grid, and assure supply of reliable and clean energy. Also, it provides flexibility to the end Consumers on their choice of energy consumption and provides flexibility to become 'Prosumers'.
- Education services, which could see a major overhaul in the way it operates and delivers education.
- Smart Home providers, triggered by the changing needs of home entertainment, home convenience services, home security, remote home monitoring and control.
- Safety and Surveillance Providers, whose business are expected to grow rapidly with increasing global crime and terrorism.
- Content Service Providers, as new content and delivery mechanisms with the help of virtual and augmented reality, must be evolved driven by consumer demands.
- Enterprise or business, as it impacts the way the companies would work in future. Other businesses like Retail businesses, which are being disrupted by virtual reality and augmented reality services.
- IoT/M2M System Integrators, whose businesses would grow exponentially with the expectation of billions of devices of to be interconnected globally.

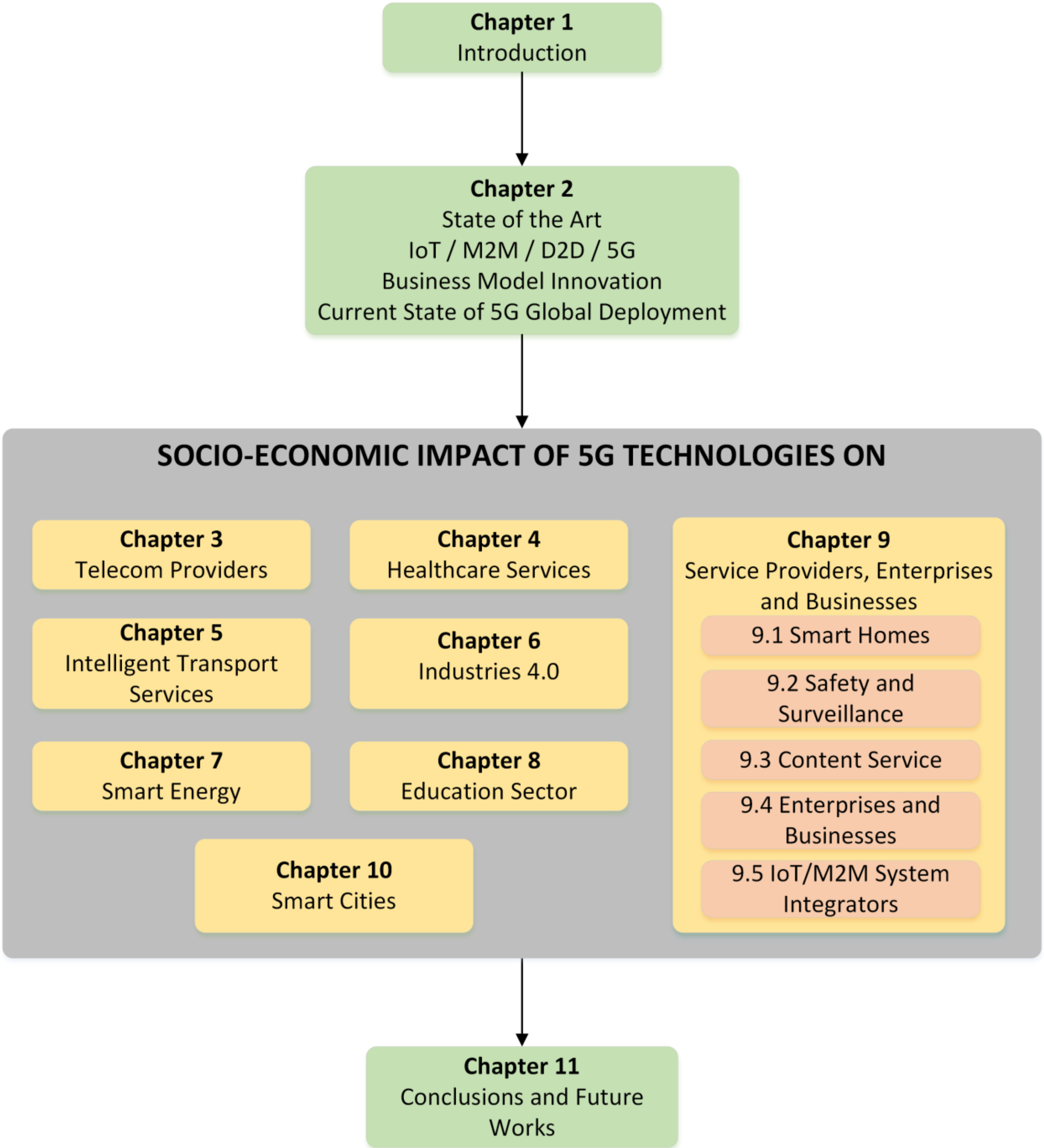

Figure 1.1: Overview of contributions and correlation of thesis chapters

Figure 1.1 above, gives an overview of contributions and correlation of thesis chapters.

1.4 Outline of the Thesis

The thesis presents the novel contributions and results on research in the impact of 5G Technologies and is organized as follows.

Chapter 2 – State of the Art

This chapter presents an overview of the state-of-the-art technologies like M2M, IoT, D2D and the emerging 5G. 5G technology is described in detail. The importance of Business model innovation is described. The current state of 5G global deployment is tracked and listed. Standardization activities in 5G is discussed along with the state of readiness technology providers. 5G deployment in regions including Asia, Europe, Americas, Australia, India, and UK are explored.

Chapter 3 – Telecommunication Providers

Telecommunication networks form the backbone of a global connected world. The greatest impact of 5G technologies is in Telecommunication services. Here, the global trends in Telecommunication business are explored. The market demands including consumer and business demands are analysed. The features of 5G in meeting these demands are discussed. The socio-economic impact of 5G on Telecom Operators are analysed. Finally, the impact on the Telecom Operator's business models is discussed. Various possibilities in Telecom business models are presented and the right approach is suggested for this industry to innovate its business model to harness the opportunities presented and stay competitive [REF: Author's publication at Sl no 3 of Sec 1.5].

Chapter 4 – Healthcare services

Healthcare services are extremely important for the social wellbeing of society. They can be vastly improved by use of telecommunication networks / services by giving accessibility of health services to under-served especially elderly and those in remote areas. In this chapter, the global trends in healthcare services are explored. The requirements of people requiring healthcare and the providers of healthcare, are analysed. The role of 5G in meeting these requirements are discussed. The socio-economic impact of 5G on Healthcare Services are analysed. The business models that healthcare industry should adopt, is presented.

Chapter 5 – Intelligent Transport Systems

Efficient transport is vital to the economy of societies. Population increase along with need for transport for work and business, necessitates more travel and results in traffic congestions and accidents. This demand needs for Intelligent transport services which includes Advanced Traffic Management systems and Intelligent Vehicles like connected cars, autonomous vehicles and unmanned air vehicles, which must have the capability to understand the environment around them and act in response to that environment without much assistance from a human being.

In this chapter, the concept of Intelligent Vehicles is first explained. The global trends in this domain are explored. The demand drivers for the Intelligent transport services, including requirement of consumers, businesses, and regulations, are analysed. The features of 5G in meeting the demands, are discussed. The socio-economic impact on the Transport services is analysed. The business models that the Transport industry should adopt, is presented [REF: Author's publication at Sl no 4 of Sec 1.5].

Chapter 6 – Industries 4.0

Industries 4.0 involves robotic assisted manufacturing where the global manufacturing system elements communicates with each other to form intelligently resulting in high productivity. In this chapter, the author has traced the evolution of Industrial revolution and the technologies that have attributed to their progress. Some of the global trends in this domain are explored and the market drivers for this are discussed. Current limitations of communication technology in implementing Industries 4.0 are analysed and the role of 5G technologies as its technology enabler, is discussed. The social and business impact of Industries 4.0 is analysed. Finally, the author has discussed business models that could be followed in an Industries 4.0 scenario [REF: Author's publication at Sl no 2 of Sec 1.5].

Chapter 7 – Smart Energy

Energy is crucial for the survival of societies and touches every aspect of our lives. Advancements in energy generation, transmission and distribution has resulted in the need for Smart Energy management consisting of Smart grids and smart metering. Smart grid introduces seamless integration of emerging technologies in the field of monitoring, automation, communication, and IT systems. Smart Energy enabled by 5G technologies, will shift many of the centralized command and control towards a mix of central and distributed control structure, giving more power to the end consumer on the choice of energy consumption.

In this chapter, the global trends in smart energy is explored. The consumer, business and regulatory demands are analysed. The features of 5G in meeting these demands are discussed. The social and business impact of 5G enabled Smart Energy, are analysed. The business models to be followed by Utilities and Private energy producers are presented.

Chapter 8 – Smart Education

Rapid technological advancements happening today is disrupting job markets and subsequently has a profound impact on education with the need to impart new types of skills with flexible delivery methods. Advances in mobile technology like 5G, IoT and Tactile Internet; can open a new chapter in education leading to Smart Education**.**

In this chapter, the global trends in Education sector is explored. The requirements of the learners and the education providers are analysed, leading to the demand drivers for Smart Education. The role of 5G in furthering the education and learning experience is discussed. The social and economic impact of smart education is analysed. Suitable business models for the education sector is presented.

Chapter 9 – Service Providers and Businesses

Technological advancements in wireless technologies like 5G, will have profound impact on the Service Providers and businesses. In this chapter, the impact of 5G on System Integrators like Smart Home Automation providers, Safety & Surveillance providers, Content Service Providers, Enterprises and Businesses like Retail and IoT/ M2M System Integrators, are analysed. Their global trends are explored. The consumer and the business drivers are analysed. The features of 5G that enable these requirements, are discussed. The social and economic impact are analysed. Suitable business models are presented.

Chapter 10 – Smart Cities

Smart Cities are the engine for socio-economic growth of societies. Here, the different independent services to the citizens are integrated by telecommunication connectivity and delivered in an efficient manner. This 'Integrated Vision" requires excellent co-ordination enabled by connectivity, amongst various multi-stakeholders in the Smart City eco-system, to make it successful and improve Citizens' Quality of Life.

This chapter analyses the global trends in Smart Cities and the various demand drivers from the citizens, governance and businesses necessitating the 'smartness' in the city, leading to the role of ICT technologies in their implementation. Further, the limitations of the current ICT systems are analysed, and the role played by 5G technologies in implementing them, is discussed. The social economic impact by listing out few Smart City applications and services enabled by 5G, are discussed. The business model ecosystem, for successful Smart City implementation, is presented [REF: Author's publication at Sl no 1 of Sec 1.5].

Chapter 11**:** The author discusses the challenges in 5G implementation and recommends policy changes for Governments to ensure successful rapid 5G deployments. Further, the author concludes with a discussion on future direction of work required in this area.

1.5 List of Publications from this Research Work

1. **Rao SK, Prasad R; "Impact of 5G Technologies on Smart City Implementation"** 2018, Springer Wireless Personal Communications, 100(1), 161-176 DOI: 10.1007/s11277-018-5618-4
2. **Rao SK, Prasad R; "Impact of 5G Technologies on Industry 4.0"** 2018, Springer Wireless Personal Communications, 100(1), 145-159 DOI: 10.1007/s11277-018-5615-7
3. **Rao SK, Prasad R; "Telecom Operator's Business Model Innovation in a 5G world"** 2018, River Publishers – "Journal of Multi Business Model Innovation and Technology" DOI: 10.13052/jmbmit2245-456X.431
4. **Rao SK, Prasad R; Book Chapter "Applications of CONASENSE", River Publishers** "Towards Future Technologies for Business Ecosystem Innovation" ISBN: 9788793609778; e-ISBN : 9788799923700

The signed Co-Author declaration statements for all the above four publications are enclosed in Appendix D.

The author (PhD student) has essentially done all the work required for the identification of the scientific problem, design & development, studies/data collection, result interpretation, writing the first draft of the manuscript, finalization of the manuscript and submission.

Details of the above work are as follows:

1)" Impact of 5G Technologies on Smart City Implementation" – Author had described the concept of Smart Cities and various services & applications required to make it happen. Role of ICT in described along with their current challenges to implement smart cities. Further, the role played by 5G as an enabler of Smart Cities, is explained along with few use cases.
Smart cities have become very essential for countries which are witnessing rapid urbanization. This paper contributes to the successes of Smart City implementation by showing how huge number of devices, people, systems, utilities, and departments could get interconnected through 5G, leading to a smarter society.

2) "Impact of 5G Technologies on Industry 4.0" – The author has traced the evolution of the industrial revolution and the technologies that have impacted them. Further, the author has described the ICT requirements to implement Industries 4.0 and the challenges in their implementation. The demand drivers for Industries 4.0 are identified and role of 5G in meeting these demands and leading to Industries 4.0 are discussed. Industries 4.0 use cases are listed.

This paper contributes to show the relevance of 5G in advancement of Industries 4.0 leading to higher productivity and quality and thereby higher GDP for the country. Also, the likely social disruption caused by Industries 4.0, is explored

3) "Telecom Operator's Business Model Innovation in a 5G world" – The author has discussed the impact of 5G on Telecom Operators, who play a major role in implementation of communication networks. Robust communication networks play an important role in the socio-economic development of a country. The advent of 5G could bring in lot of opportunities and challenges for the Telecom Operator. Here, the author looks at the current business strategies and challenges faced by these Operators and discusses the changes they must adopt in their businesses to remain competitive, with the advent of 5G. This paper contributes to the successful adoption of 5G by the Telecom Operators, which are critical to countries socio-economic development of the country.

4) Chapter "Applications of CONASENSE" in a book titled "Towards Future Technologies for Business Ecosystem Innovation" – The vision of CONASENSE is to integrate Communications, Navigation, Sensing and Services. The goal of this "integrated vision" is to improve the user's Quality of life.
This paper describes the role of Satellites and Unmanned Air Vehicles (UAVs) in implementing the integrated vision of CONASENSE. It lists out various CONASENSE applications enabled by Satellites and UAVs, in disaster and emergency response management, intelligent transport systems, utilities, healthcare, agriculture and country's defence.

1.6 Conference Presentations of the Author's Research Work

Conference Presentations:

1. S. Rao,"5G-Special Session – Role of ICT in CONASENSE", IEEE 5G Summit & 33rd GSSM, New Delhi, India, Jun 2019
2. S. Rao, "5G- Smart Cities and communities", IEEE 5G Summit & 32nd GSSM, Ranchi, India, Dec 2018
3. S. Rao,"5G and Beyond" BITSA International World Connect 2018, Goa, India, Nov 2018
4. S. Rao,"5G-Smart Cities Implementation", WWRF Meeting 41, Herning, Denmark, Oct 2018
5. S. Rao, "How should India take up 5G and beyond", IEEE "5G and Beyond" Summit & 31st GSSM, New Delhi, India, June 2018
6. S. Rao, "5G-Impact on Smart Cities and Environment", IEEE 5G Smart City Summit and 29th GSSM, Bhubaneshwar, India Aug 2017

7. S. Rao, “5G Use Cases- Drivers/ Trends/ Impact”, IEEE International 5G Summit and 28^{th} GSSM, Kolkata, India, March 2017
8. S. Rao, “5G-Enabler for Smart Cities”, IEEE 5G Smart City Summit and 27^{th} GSSM, New Delhi, India, Dec 2016
9. S. Rao, “5G CONASENSE- Different Aspects”, International Workshop on 5G CONASENSE, Mumbai, Sep 2016
10. S. Rao.”5G-Enabler for IoT”, IEEE Workshop on 5G Internet of Things and 25^{th} GSSM. Bangalore, India, Jul 2016
11. Invited Panellist at National Geography’s “Big Energy Question” panel debate on the topic of “How can Digital Technology transform our Energy Future” held during CeBit 2015 during Oct 2015
12. S. Rao, “5G-Applications and Business Models”, “3^{rd} International Conference C5 and Workshop on 5G Applications & Business Models and 19^{th} GSSM, Surat, India, Jan 2015
13. S. Rao. ”IoT-How Technology is changing life”, “3^{rd} International Conference C5 and Workshop on 5G Applications & Business Models and 19^{th} GSSM, Surat, India, Jan 2015
14. S. Rao,” Business Impact of 5G Technologies”, 5G Standardization Workshop: WISDOM, New Delhi, Sep 2014
15. S. Rao,”M2M Scenario in India”, Keynote Speaker at the seminar ‘Taiwan-India Industry Cooperation and Networking” organised by Government of Karnataka, India, Sep 2014.

Conference Session Chairman

1. S. Rao,” International Symposium on 5G & Beyond for Rural Upliftment” IEEE 5G Summit, IIT Dhanbad, India, Feb 2020.
2. S. Rao, “5G and Device-to-Device Communication”, Global Wireless Summit 2015, Hyderabad, India, Dec 2015

1.7 Method of Study

This is an Industrial based research with practical applications impacting the industry and society. The author is an experienced industry practitioner having 36+ year global experience in the domain of the Information and Communication Technologies having played leading roles in technology and business development in leading Telecom Product OEMs, Telecom Service Providers, Telecom Software product companies and leading IT companies.

The Author has undertaken the Qualitative study in line with Validity Network Schema defined by Mcgrath. [1]. The study has been conducted in three stages,

1.7.1 Stage 1 – Analysis of Industry sectors and research questions

In this stage, Author has studied the state of the art, focussing on M2M, IoT, D2D, 5G, Business Model Innovation and Current state of 5G global deployment as a background study to his research work. He has researched the use case possibilities of M2M, IoT and 5G and looked at global trends across various sectors. From this, he has gathered information about what sectors would potentially get impacted by 5G. Based on that, he has decided the following sectors

1. Healthcare
2. Industries 4.0
3. Intelligent Transport System
4. Smart Energy
5. Smart Education
6. Telecom Service Provider
7. Smart Homes
8. Safety & Surveillance
9. Content Service Providers
10. Enterprises
11. Retail
12. IoT/ M2M System Integrators
13. Smart Cities

He has made initial desk research of the global trends in each of the chosen sector.

He has formulated research questions addressing each of the chosen domain, which are tabled below:

In the Telecom Service Provider domain, the research questions include:

- What are the global trends in Telecom domain?
- What drives Telecom Consumers for increased usage of telecom services?
- What is the Quality of Service expectation for a telecom subscriber?
- Other than the basic calling features of a phone what do consumers expect from their devices? – Is it OTT services like social networking? entertainment? games? News? Online services? Education?
- Consumer demands
- What have been the traditional Telecom operator business models?
- What are the challenges to the traditional Telecom operator business models?
- What kind of telecom services do businesses need?
- What kind of new services do Telecom Service Providers want to offer
- Strategies of small and new players, entering Telecom Service Provider business?
- Are there any limitations on their current technology preventing Telecom Service Providers from offering newer kinds of services?
- How will the end consumers of telecom services be benefitted by the advanced features of 5G?
- What is the economic impact for Telecom Service Providers? What new business cases would be enabled by 5G?

- What are the new business models that telecom operators can adopt to innovate their business and remain competitive?
- What are the business opportunities for micro-operators?
- What is the business model framework that telecom operators could adopt?

In the Healthcare domain, the research questions are:

- What are the global trends in healthcare domain?
- What kind of health care services are required by people?
- Would people be comfortable in doing certain kinds of routine tests by themselves, if they have the right kind of gadgets?
- Do people like to visit hospitals for every minor problem OR would they like if they can communicate with a doctor by phone/ online and get monitored remotely?
- Why do they do not want to visit hospital for minor issues?
- What kind of healthcare facilities would be required for elderly people/ people living with assistance.?
- What kind of flexibility would people want in choosing the method of healthcare?
- What kind of new facilities do hospital need in handling emergencies and in the treatment of patients?
- What should Governments do to improve the efficiency of healthcare system?
- By implementing high performance connectivity, what kind of benefits could be benefits could be expected to public? What new possibilities can be expected?
- What economic impact can be expected for Healthcare providers? Governments?
- What business model could be adopted for a integrated healthcare system?

In the transport domain, the research questions are

- What are the global trends in Transport domain?
- What are the different types of Intelligent Transport systems?
- What would be expectation of consumers with respect to commuting?
- What kind of technology advancement are being done by vehicle manufacturers?
- What are requirements of transport service providers?
- What are regulations and policy decisions required by to be taken by Governments to ensure efficiency and safety?
- How does 5G support intelligent transport systems?
- What benefits can intelligent transport system like connected commuting, autonomous vehicles and UAVs bring to consumer?
- What economic impact can be experienced by vehicle manufacturers, transport service providers and Government agencies?
- What kind of value can be created from data obtained from connected vehicles?
- What new business models can be adopted in the intelligent transport systems domain?
- What could be the challenges to the successful implementation of intelligent transport systems?

In the Industries domain, the research questions would be

- What are the broader features of Industries 4.0?
- What are the global trends in Industries 4.0?
- What are the requirements of Industries to increase their efficiency of operations?
- What is the expectation of factory workers with respect to safety?

- Are there any technology limitations in implementing Industries 4.0?
- How can 5G support Industries 4.0?
- What can kind of benefits can be expected from implementing Industries 4.0 about productivity, efficiency, quality, and revenues?
- Examples of successful implementation?
- How does industrial automation impact jobs?
- What economic benefits can be expected from industrial automation?
- What regulatory policies should Government bring in to safeguard employment, ensure safety & security of workers, incentives to industries to promote efficiency?
- What new business model can be adopted for Industries 4.0?

The research questions in the Energy sector would be:

- What are the global trends in Smart Energy?
- What are the expectations from consumers in the energy sector?
- What are the requirements for the Energy utility companies to increase their efficiency and meet the regulatory requirements? How should they charge the consumers?
- What are the typical regulatory / legislative initiatives in energy sector?
- How can 5G be a technology enabler for Smart Energy systems
- How are Consumers benefitted by Smart Energy?
- What is the economic impact for Utility companies? What new opportunities can be created?
- What new business model can be adopted for Energy sector?

The research questions in the Education sector would be:

- What are the global trends in education sector?
- What are the expectations of Learner?
- What are the expectations of Education Provider?
- How can 5G be a technology enabler for Smart Education systems
- What are the benefits for the Learners with the implementation of Smart Education enabled by connectivity?
- What are the new opportunities for the education service provider?
- What new business model can be adopted for Education sector?
- Any foreseen challenges in implementing Smart Education?

The research questions for Smart Home sector:

- What are the global trends in smart home sector?
- What are the expectations of homeowners?
- What are the requirements of the Smart Home Service Providers?
- How can 5G be a technology enabler for Smart Home systems
- What is the impact of Smart Homes and what are the opportunities?
- What new business model can be adopted for Smart Home sector?

The research questions for Safety & Surveillance Providers:

- What are the global trends in security domain?
- What are the expectations of consumers / service providers and regulators?
- What is the impact of Smart Security Homes and what are the opportunities?

The research questions for Content Service Providers:

- What are the global trends in this domain?
- What are the expectations of consumers?
- What is the impact of Smart Content and what are the opportunities?
- What new business model can be adopted for Content Service Provider?

The research questions for Enterprise and Businesses:

- What are the global trends in enterprise and retail domain?
- What are the expectations of consumers and businesses?
- What is the impact on Enterprises and retail businesses?
- What new business model can be adopted?

The research questions for IoT/M2M System Integrators?

- What are the global trends in this domain?
- What are the expectations of consumers and system integrators?
- What is the impact on Enterprises and retail businesses?
- What new business model can be adopted?

The research questions for Smart Cities domain:

- What are the global trends in smart cities?
- What are the expectations of Citizens, Business and Government?
- What are the requirements for implementing Smart Cities and their current limitations?
- How can 5G be a technology enabler for Smart Cities?
- What is the impact of Smart Cities? What are the new opportunities in various areas of Smart Cities?
- What new business model can be adopted for Smart Cities?

1.7.2 Stage 2 - Data Sources and Data collection

Research questions and review methods are based on the Author's day-to-day interactions with Customers and stakeholders across the domains which have been addressed in his thesis.
Being a working senior industry professional with hands-on experience in the domain of his research, his method of data collection for research is based on the following:

- Professional experience gained over more three decades in leading technology and business development in global Telecom Product OEMs, Telecom Service Providers, Telecom Software product companies and leading IT companies.
- Present work - Technology & Business Development- planning and strategizing new business opportunities in IoT, M2M and Telecom domains before and during his PhD study period. This gave him the need to be technology, market and customer focussed in his area of research

- Close interaction with all the in-house research labs at Tata Consultancy Services (TCS) for planning Go-To-Market
- Keeping abreast with the developments happening globally in this field through market research
- His analysis of exploring new business opportunities which is applicable to his current job
- Co-ordination with Industry peers
- Interaction with Customers in Telecom, Healthcare, Manufacturing, Power sector, Enterprises, Smart City Missions etc as a part of his official work.
- Active participation in Global Standardization Forum of India (GISFI) and Telecommunications Standards Development Society, India (TSDSI), standardization bodies of India focussing on standard development in IoT and 5G domains.
- Close engagement with Standard and Professional Institutions like IEEE, Australian Computer Society, Computer Society of India etc, interaction with academia and researchers in this field.
- Engagement with Government Regulatory and Policy making bodies responsible for policy decisions in his research. —
    - Member of **World Health Organisation's** Special Focus Group of "Artificial Intelligence in Healthcare".
    - Chairman of 'M2M Gateway & Architecture Workgroup' setup by Department of Telecom, Government of India during 2014 and 2015. This group was formed by Government with senior representation from Academia, Industry and Government body across India, to develop roadmaps in M2M and IoT. The work contributed to the National Telecom M2M Roadmap defined by Department of Telecom. Also, Member of Healthcare, Power sector and Intelligent Transport Systems workgroups.
    - Member of National Working Group of Department of Telecom for "IoT & its application in Smart Cities".
    - Vice-Chair for the Consultative Committee on the adoption of oneM2M standards in India
    - Member of IoT group of Bureau of Indian Standards

The above engagement gave the Author excellent opportunities to frequently interact and brainstorm with Industry Leaders across his domains of research. Academia Professors & Researchers and Policy decision makers of the Government.

- Participation in International conferences in the subject of his research. Presenting his papers at the conferences. Close interaction with global subject matter experts at the conferences. These are listed in Sec 1.6

- He has been invited by the Department of Telecom of Government of India, to participate in the first 5G Smart City trial of the country at a major city in India, hailed as a model trial, to provide actionable insights for smart city managers, through his company's Big Data Analytics Platform.

Other Data Sources used:

- IQ Newsletters – Daily Wireless
- IQ Newsletters – Daily Telematics
- IR Newsletters - Daily Broadband
- IEEE-Explore
- RCR Wireless
- Fierce Wireless
- GSA Marketing
- Total Telecom
- BrightTALK
- Enterprise IoT Insights
- MarketandMarkets
- Smart Cities Connect
- Telecomasia.net
- ReadWrite Labs
- ET Telecom News
- ETTelecom Latest News
- TechRepublic News
- ET Telecom News alert
- Aurora Insights

- Workshops/Webinars of
  - HIS Markit – Technology webinars
  - OMDIA
  - ReadWrite Labs
  - Keysight Technologies
  - Nokia
  - 5G.co.uk
  - A10 Networks
  - GSMA Future Networks
  - Topio Networks
  - Voltdb
  - TU-Automotive

- Light Reading Webinars
- Enterprise IoT Insights
- 5G Digital Week

1.7.3 Stage 3 – Data analysis and 5G Socio-Economic impact discussion

The data sources and the data collection from stage 2, are used to

- Track status of global 5G deployment and Standardization activities
- Understand the global trends better in each of the domains in the research
- Determine the demand drivers for each domain based on the consumer drivers, business drivers and government regulations in those domains
- Study the current connectivity implementation to determine its suitability
- Bring out how 5G could be a Technology enabler in those domains from the connectivity perspective.
- Discuss the social impact
- Discuss economic impact through qualitative analysis, by identifying typical use cases and opportunities enabled by connectivity and aided by other technological advances.
- Bring out possible Business models to monetize or harness the opportunities
- Conclude with recommendation for the businesses and policy makers.

1.7.4 Validation of the Proposals made

Author started working on this research during 2013. There were no 5G trials happening during the initial period of the research. The author being an Industry professional, had an extensive reach to markets in all domains addressed in the research. He had proactively engaged himself in various Standardization and technology initiatives in this area, as a means of addressing the data collection and validation. He is from technology industry in business development domain and his job involves exploring futuristic business opportunities and formulating go-to-market strategies across verticals addressed in this dissertation. He has been actively involved in industry forums on IoT & 5G since last 6 years and been interacting with industry, academic and regulatory authorities since then. He has had active participation in forums like Global ICT Standardization Forum of India (GISFI), Telecommunications Standards Development Society, India (TSDSI), IEEE-Comsoc, Smart City Council etc. This is explained in detail in Section 1.7.2

The Author has been part of Government of India's official workgroups on telecom initiatives, where IoT and 5G are the focus areas. He has chaired large working groups which had representation from senior industry leaders, academicians, and policy makers. These have been explained in Section 1.7.2

Author has made 15 presentations in International conferences, in the subject of research, since 2014, which are listed in Section 1.6. He has been a Session Chair for 2 international sessions. These conferences have been well attended by Senior Industry leaders representing Telecom industry and other verticals addressed in the thesis, leading Academicians, Researchers and Government policy makers. So, his field work to validate the proposals and hypotheses made is from his first-hand experience with the stakeholders across all the domains which are addressed in the thesis. These have been well appreciated by the attendees. His presentation "Business Impact of 5G" at the very first 5G conference in India during September 2014, had been an eye-opener for the audience and was highly appreciated, as 5G was completely new to India then. In fact, Industry CEOs are talking about this now. The author has enclosed Speaker and Participation Certificates for all these.

Author has published three peer-reviewed papers in International Journals and a book chapter, as a part of his research. These are relisted in Section 1.5. These publications have been highly appreciated in the scientific world as well cited several times. He has received excellent feedback for these publications from International publishers / Institutions worldwide, on his published research papers and has been invited to join their editorial board.

1.7.5 Limitation of Study

United Nation's 'International Standard Industrial Classification (ISIC)' of All Economic Activities provides standardized reporting of economic indicators regardless of country. The 18 major industry sectors defined by ISIC are:

1. Agriculture, forestry, and fishing
2. Mining and quarrying
3. Manufacturing
4. Electricity
5. Water supply, sewerage, waste management
6. Construction
7. Wholesale/ Retail
8. Transportation
9. Accommodation
10. Information & Communication
11. Financial and Insurance activities
12. Real estate activities
13. Professional, Scientific, and Technical activities

14. Administrative and Support service activities
15. Public administration & defence; compulsory social service
16. Education
17. Human health and social work activities
18. Arts, entertainment & recreation

In this study, Author has considered the following industry sectors only and mapped it similar industry sectors defined by ISIC, UN.

1. Healthcare -- which can represent 'Human health and social work activities'
2. Industries 4.0 – which can represent 'Manufacturing'
3. Intelligent Transport System - which can represent 'Transportation'
4. Smart Energy -- - which can represent 'Electricity, gas, steam, A/C'
5. Smart Education – which can represent 'Education'
6. Telecom Service Provider - which can represent 'Information & Communication'
7. Smart Homes – which can represent 'Accommodation'
8. Safety & Surveillance – which can represent 'Public administration & defence'
9. Content Service Providers – A which can represent 'Arts, entertainment, recreation'
10. Enterprises --which can represent 'Financial & Insurance activities'
11. Retail -- which can represent 'wholesale and retail trade'
12. IoT/ M2M System Integrators -- which can represent 'Professional, Scientific & Technical'
13. Smart Cities --which can represent 'Public administration & Defence, Administrative and support service activities', 'Water supply, sewerage, waste management'

The following industry sectors defined in ISIC, has not been included in this research

1. Agriculture, forestry, and fishing
2. Mining & quarrying
3. Construction
4. Real estate activities

The potential social and economic impact of 5G technologies, on the above four sectors, have not been considered in this research.

My research will be limited to Qualitative study only. However, I have also made quantitative analysis in few sectors, which compares with international estimates.

References

[1] McGrath J.E, Brinberg D , "Validity and Research Process" Sage Publications 1985

2.0 State of the Art

2.1 Introduction

This section describes various technologies involved like Machine to Machine (M2M) communications, Internet of Things (IoT), Device to Device (D2D) and 5G. The concepts of Business Models and Business Model Innovation are also discussed. Finally, the current state of global deployment of 5G Technologies is discussed.

2.2 Machine-to-Machine (M2M)

M2M, the acronym for Machine-to-Machine communication, is an emerging area in the field of telecom technologies. Machine to machine (M2M) refers to technologies that allow both wireless and wired systems to communicate with other devices of the same ability. M2M uses a device (such as a sensor or meter) to capture an event, which is relayed through a network (wireless, wired or hybrid) to an application, that translates the captured event into meaningful information. M2M Communication when combined with logic of cloud services and remote operation becomes “Smart”.

ETSI defines M2M Communications in ETSI TR 102 725 V1.1.1(2013-06) as *Physical telecommunication-based interconnection for data exchange between two ETSI M2M compliant entities, like: device, gateways and network infrastructure* [1].

3GPP defines M2M communications as a form of data communication between entities that do not necessarily need human interaction. This new type of M2M communication may in future become more relevant as M2M is a future growth sector in mature markets and the ubiquitous coverage of mobile networks is main enabler. Also, potential enhancements of 3GPP standards would be a stimulator [2].

IEEE defines M2M Communication as the information exchange between user devices through a Base Station, or between a device and a server in the core network through a Base Station that may be carried out without any human interaction [3].

IBM describes M2M as the interaction of billions of devices and machines that are connected to the internet and each other. They can communicate and share information without the need for human interaction [4].

In M2M communication, machines can be interconnected through host of media depending on the specific requirements i.e. Indoor Electrical Wiring, Wired Networks (IEEE 802.3 Ethernets), WPANs (Bluetooth, Dash7, ZigBee etc.), Wi-Fi (IEEE 802.11), PLC, PSTN/ DSL, 2G/3G/4G or even satellites.
Machines are having capability of communication with other machines for decades. But availability of Inexpensive electronics, use of Internet Protocol (IP) along with ubiquitous network availability and cloud computing has vastly enhanced the possibility of devices equipped with communication module

capable of providing their status and other information, which can be aggregated, interpreted and can be in turn used to control these devices or can be used in more meaningful ways.

Machine to machine (M2M) communication is a key enabler of applications and services across a broad range of vertical markets. Machine-to-machine communication is one of the largest growth markets and is regarded in many sectors as a driving force for innovation. Machine-to-Machine (M2M) communications represent tremendous opportunities, as roll-out becomes more widespread across various sectors. M2M can bring substantial and tangible social and economic benefits to consumers, businesses, citizens, and governments. M2M is the basis for automated information interchange between machines and a control centre for various industry verticals like Smart City, Smart Grid, Smart Water, Smart Transportation, Smart Health etc.

Traditionally, there have been two types of infrastructure: physical (buildings, roads, vehicles, transportation, power plants for example) and digital (IT and Communications infrastructure). There is a distinction between these two types of infrastructures – physical and digital, with both operating on separate fields. A convergence of the two coupled with smart management of the different infrastructures, could provide a multiplier effect and the same is the basis of M2M proliferation.

M2M Ecosystem comprises of telecom service providers, M2M application service providers, Sensors, hardware OEMs, supply chain, middleware, deployment, and asset management.

M2M is driving an increasingly complex relationship between networks, service providers and an exploding number of devices in real time. These devices will be powered and connected by a complicated convergence of networks. Different types of applications have different needs in terms of network resources leading to requirement of different regulatory treatment to them.

The M2M market is segmented and most of the M2M solutions have been designed for vertical/industry specific applications. This affects the development of large scale M2M solutions. The M2M device space is growing tremendously, thus introducing a wide variety of disparate M2M devices in the market. It poses many technical challenges in terms of security, device data management, discovery, etc. There is tremendous growth opportunity for M2M applications and for low cost M2M devices having reasonable computing power coupled with long lasting battery.

With traditional revenue streams getting saturated in most markets around the world, M2M holds the promise of generating new avenues for revenue generation for TSPs/ ISPs as well as opening new business opportunities for new service providers.

Today industry is at the cusp of the new operating paradigm, marked most significantly by a transition from voice & data to M2M/ IoT and associated services and offerings. Traditional businesses, which earlier had nothing to do with IT, have not only started adopting it, but at the same time getting heavily dependent on IT.

M2M applications like remotely operated irrigation pumps, Smart Grid etc. and can play significant role in boosting a country's economy. Current applications of M2M cover many areas and can be broadly grouped under:

- Transportation & Automotive
- Utilities
- Financial Transactions in Retail
- Home/Buildings:
- Security and Surveillance:
- Manufacturing
- Healthcare
- Consumer Electronics:
- Other Sectors:

M2M applications have a great potential to transform businesses. M2M communication will challenge companies to be innovative in the same way as mobile internet did. Given the diverse nature of M2M applications, some sectors will be more successful/ innovative and emerge as winner than other sectors. However, for M2M to gain acceptance among the general populace, service providers and others must deliver applications that bring tangible value to people's lives.

M2M has the power to reinvent business. The combination of backend service enablement platforms, service delivery platforms and intelligent devices in the field remove barriers that were previously hindering M2M market growth. In the coming years, millions of motor vehicles, utility meters, consumer electronics, tele-health/medical devices, security alarms and other machines will become networked using M2M, advanced service enablement and service delivery platform technologies.

Service delivery platforms provide a software service infrastructure that can manage multiple wireless edge device environments and store all the edge data in a single database environment. Applications can use that data for a variety of reporting, management and service enablement purposes. Such service delivery platform should provide standards-based services and tools to:

- Collect and process data from multiple wireless devices
- Integrate data collected into existing applications and IT systems
- Manage wireless device provisioning, deployment and updating
- Secure remote access to control and manage assets

Through these tools, carriers and Mobile Virtual Network Operators can deliver vertical market solutions that enable customers and enterprises to access remote assets with real-time visibility for improved decision making. M2M can connect virtually anything. The result has been an explosion in the number of possible business and consumer M2M applications.

With technological, political, and economic factors coming together; M2M will continue to see strong growth. As new infrastructure replaces the old, companies and governments can drastically alter their businesses by implementing a technology strategy that is not only more efficient but enables new levels of service and economy.

Flexible, intelligent devices make M2M a transforming technology that enables businesses to simplify, renovate and enhance in entirely new ways. Coupling these devices with a robust service enablement and delivery platform makes these deployments scalable today, delivering actionable data directly into the enterprise applications. It enables in dynamically managing the end-to-end solutions from deployment to full life cycle, including billing and expense management. The possibilities are endless.

The program of an embedded system may be the only program that will run on the system and provide all its functions. The firmware will be held in memory devices which are permanently installed on the device and cannot be changed after manufacture. This could be in the form of an embedded SIM. These devices would be operational on systems in faraway places or may be on moving vehicles. The device needs to be provisioned initially through 'Over the Air (OTA)" programming. There might be also be a requirement of updating the program for fixing bugs or for adding new features to the device. It will be required to perform this update 'Over the Air" through a robust communication system and very securely [5].

2.3 Internet of Things (IoT)

ITU-T in its recommendations, ITU-T Y.2060 (06/2012) has defined Internet of things (IoT) as "Global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies. Through exploitation of identification, data capture, processing, and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled." [6].

IETF defines IoT as the network of physical objects or "things" embedded with electronics, software, sensors, and connectivity to enable objects to exchange data with the manufacturer, operator and/or other connected devices [7].

Gartner defines IoT as the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment [8].

Internet of Things extends the communication among all the things that surround us, through Internet.

M2M is a subset of IoT. The semantic origin of the expression is composed by two words and concepts: “Internet” and “Thing”, where “Internet” can be defined as “The world-wide network of interconnected computer networks, based on a standard communication protocol, the Internet suite (TCP/IP)”, while “Thing” is “an object not precisely identifiable” Therefore, semantically, “Internet of Things” means “a world-wide network of interconnected objects uniquely addressable, based on standard. IoT enables connection between Any THING (PCs, Human to Human, Human to Thing, or Thing to Thing) at Any PLACE (Indoors, outdoors, on the move) at any TIME (night, day).

The differences between IoT and M2M are listed in the Table below:

M2M	IoT
It is about direct communication between machines	It is about sensor automation and internet platform.
Supports point-to-point communication usually embedded within hardware at the customer site	Devices communicate using IP networks and also supports cloud communication
Devices do not necessarily rely on an internet connection	Devices require an active internet connection
Limited integration options as devices must have corresponding communication standards	Unlimited integration options. Needs solution to manage all of the communication.
M2M is mostly hardware-based technology	IoT is both hardware and software based
Typically, data from M2M systems are only leveraged in single simple applications. They are usually utilized in point solutions in service management applications. These are mainly related on the maintenance level [9].	Device and sensor data can be integrated with big data, analytics and other enterprise mobile applications. Apart from providing maintenance, IoT also improves business process and operations.

TABLE 2.1: Differences between M2M and IoT

IoT refers to any system of interconnected people, physical objects, and IT platforms, as well as any technology to better build, operate, and manage the physical world via pervasive data collection, smart networking, predictive analytics, and deep optimization. Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization. Internet of Things brings together people, process, data, and things to make networked connections more relevant and valuable than ever before – turning information into actions that create new capabilities, richer experiences, and unprecedented economic opportunity for businesses and individuals. Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization. The Internet of Things—embedding sensors and actuators in machines and other physical objects to bring them into the connected world—is spreading rapidly. From monitoring the flow of products through a factory to measuring the moisture in a field of crops to tracking the flow of water through utility pipes, the Internet of Things allows businesses and public-sector organizations to manage assets, optimize performance, and create new business models. With remote monitoring, the Internet of Things also has great potential to improve the health of patients with chronic illnesses and attack a major cause of rising health-care costs.

Benefits of IoT

- Real-time monitoring- for efficient decision making and action.
- Better transparency of physical flows and detailed status information. This is also important for regulatory compliance and public dissemination.
- Improved performance, visibility & scalability of business process automation.
- Creation/transformation of new and existing business processes by enhancing efficiency, accuracy, mobility and automation

Key areas of IoT being used today

- Agriculture
- Automotive
- Consumer products
- Energy and Utilities
- Government
- Healthcare
- Home Automation
- Insurance
- Manufacturing
- Oil and Gas
- Transport

2.4 Device-to-Device (D2D)

D2D is currently being specified by 3GPP in LTE Rel-12, focusing on Public Safety applications and proximity-based services (device discovery). D2D communication is recognized as one of the technology components of the evolving 5G architecture by the European Union project METIS. METIS stands for Mobile and wireless communications Enablers for the Twenty-twenty Information Society. The main objective of the project was to lay the foundation of 5G, the next generation mobile and wireless communications system. The METIS project evaluated the role that D2D technology can play in various scenarios such as vehicle-to-vehicle communication; national security and public safety, cellular network offloading or service advertisement [10].

In a conventional cellular system, devices are not allowed to directly communicate with each other in the licensed cellular bandwidth and all communications take place through the base stations. Device-to-Device (D2D) communication refers to a radio technology that enables devices to communicate directly with each other, that is without routing the data paths through a network infrastructure. Device terminal relaying makes it possible for devices in a network to function as transmission relays for each other and realize a massive ad hoc mesh network. Figure 2.1 illustrates the principle of D2D communication.

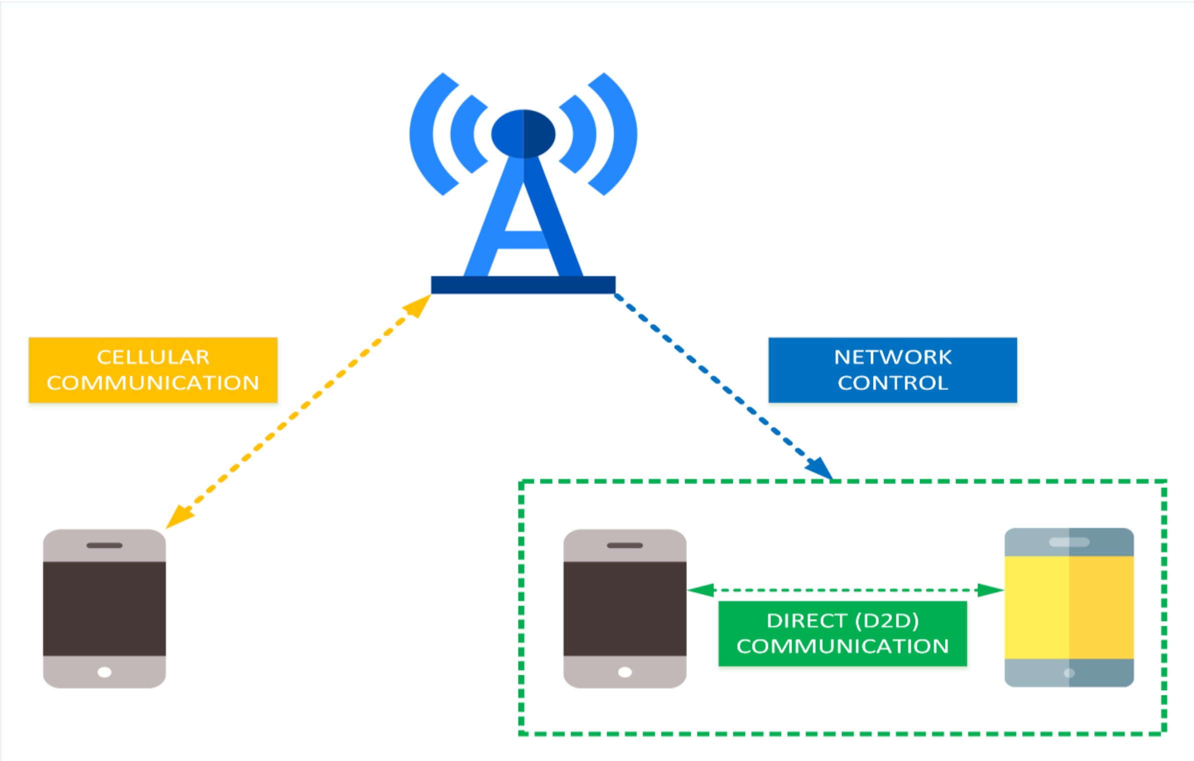

Figure 2.1: Device-to-Device Communication

Potential Use cases of D2D are: [10]

- Proximity-based services where devices detect their proximity and subsequently trigger different services (such as social applications triggered by user proximity, advertisements, local exchange of information, smart communication between vehicles, etc.).

- Public safety support, where devices provide at least local connectivity even in case of damage to the radio infrastructure. D2D could be of critical use in natural disasters like earthquake or hurricane.

Possible D2D architectures: [11]

1. Device relaying with operator-controlled link establishment (DR-OC)

   A device at the edge of a cell or in a poor coverage area can communicate with the BS through relaying its information via other devices. This allows for the device to achieve higher QoS. The Operator controls the link establishment.

2. Direct D2D communication with operator-controlled link establishment (DC-OC)

   The source and destination devices talk and exchange data with each other without need of a BS, but they are assisted by Operator for link establishment.

3. Device relaying with device-controlled link establishment (DR-DC)

   Operator is not involved for link establishment. Source and destination devices are responsible for coordinating communication using relays between each other.

4. Direct D2D communication with device-controlled link establishment (DC-DC)

   Source and destination devices have direct communication with each other without any operator control.

Potential gains using D2D are: [10]

- Capacity gain: due to the possibility of sharing spectrum resources between cellular and D2D users.
- User data rate gain: due to the proximity and potentially favourable propagation conditions high peak rates may be achieved.
- Latency gain: when devices communicate over a direct link, the end-to-end latency may be reduced.
- QoS - The network controls and optimizes the use of the resources for both Cellular communication and D2D, resulting in enhanced performance and quality of service.

Challenges in D2D: [10]

- Security: Since the user data is routed through other users' devices, security must be maintained for privacy. The parties sending and receiving the data must be assured their data is not accessible to the relay, and the relay must be assured the data it is handling is benign.

- Interference management: To ensure minimal impact on the performance of existing macrocell BSs, the two-tier network needs to be designed with smart interference management strategies. D2D designs must carefully manage channels designated exclusively for D2D connections, as well as channels jointly used by both D2D connections and connections with the base station.
- Resource Allocation: Appropriate resource allocation schemes to be made. Under the DR-OC and DC-OC designs, for example, the base station can (partially) manage the relay and channel selections. Under the DR-DC and DC-DC designs, however, there is no centralized supervision on either relay selection or channel management. Resources can be allocated in two ways
    - Dedicated Resources – A fraction of the total available cellular resources is allocated for direct D2D communication
    - Reuse Resources – resources are reused between cellular UEs and direct D2D communication. On a per-TTI/resource basis, a decision is made on whether that resource should be allocated to D2D or cellular or both

- The most important practical problem is that of incentivizing users to lend their devices to serve as relays for the traffic of others, especially since these connections will consume bandwidth, storage, and battery power on the relay.

Impact for the Service Provider

Novel pricing models could be designed to tempt devices to participate in this type of communication. Pricing schemes must be developed for different types of device relaying

For DR-OC designs, the operator may incentivize users to lend their devices as D2D relays by offering a bill reduction in proportion to the amount of data relayed that month.

For DC-OC designs, the challenge is to incentivize users to use D2D communications instead of free WiFi or Bluetooth connections.

Finally, for DR-DC and DC-DC designs, the operator is external from the connection, and as such the two parties involved should agree on a pricing scheme (or simply not charge for the relay). This means that Operator will not get revenue.

2.5 5G Technologies

Technologies that have the greatest potential to drive substantial economic impact and disruption by 2025 can come in any field or emerge from any scientific discipline, but they share four characteristics: high rate of technology change, broad potential scope of impact, large economic value that could be affected, and substantial potential for disruptive economic impact. Therefore, technologies that the author believes will have significant potential to drive economic impact and disruption by 2025, are 5G. Emerging Technologies which have the potential to disrupt the status quo, alter the way people live and work, rearrange value pools, and lead to entirely new products and services. 5G has the power to transform our world, business leaders, policy makers, and citizens must look ahead and plan. In just a few years, Internet-enabled portable devices have gone from a luxury for a few to a way of life for more than one billion people who own smartphones and tablets. Ubiquitous connectivity and an explosive proliferation of apps are enabling users to go about their daily routines with new ways of knowing, perceiving, and even interacting with the physical world. The technology of the mobile Internet is evolving rapidly, with intuitive interfaces and new formats, including wearable devices. The mobile Internet also has applications across businesses and the public sector, enabling more efficient delivery of many services and creating opportunities to increase workforce productivity. In developing economies, the mobile Internet could bring billions of people into the connected world.

2.5.1 Evolution of 5G

There has been a rapid evolution of radio technologies since the launch of analogue cellular systems in 1980s, termed as 1st Generation or simply 1G. Thereafter, digital wireless communication systems are consistently being evolved, one generation being advanced every decade.

The Second Generation (2G) happened in 1990s, primarily using the GSM standard and using digital transmission instead of analogue transmission, which had the benefit of lower battery power consumption. SMS text messaging was introduced.

The Third Generation (3G) came in 2000s, bring in high-speed IP data networking. Packet switching was used for data transmission as against circuit switching done earlier. This enabled media streaming of digital content to 3G handsets.

Fourth Generation (4G) in 2010s saw the growth of mobile broadband, with improvements in speed up to 10-fold over 3G and was an extension of 3G with higher bandwidth and services. Data transfer speed up to 100 Mbits/s downloads is possible in 4G Long Term Evolution [12].

Now we are progressing towards Fifth Generation (5G) in 2020 [13]. We are advancing towards more and more sophisticated and smarter technology. The features of 5G has the potential to change the meaning of mobile communications enabling revolution in connected society.

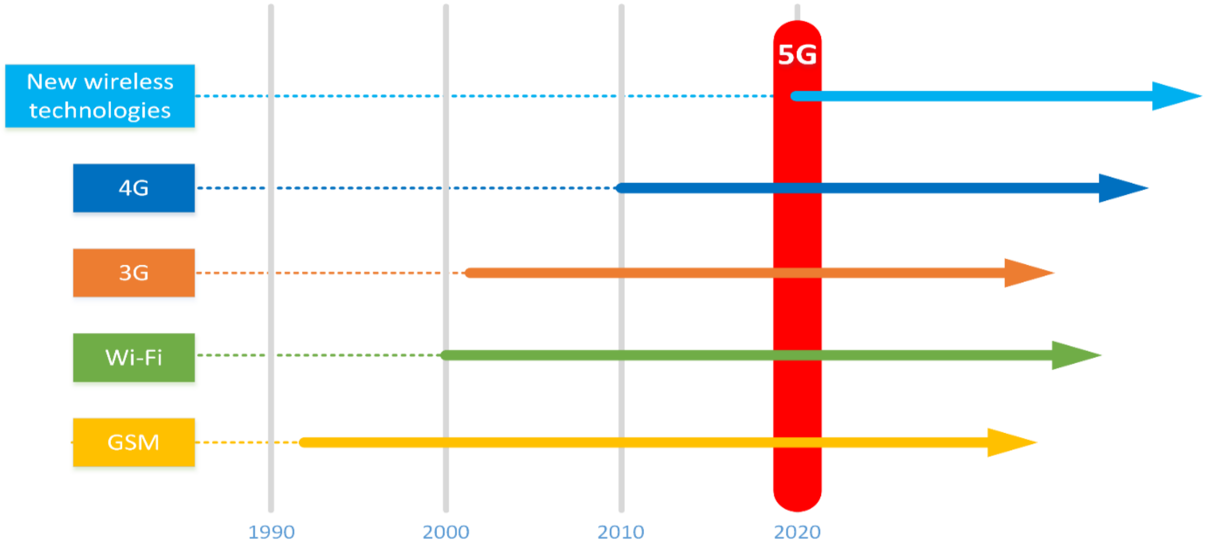

Figure 2.2: Evolution towards 5G

5G will naturally evolve from existing 4G networks but will mark an inflection point in the future of communications, bringing instantaneous high-powered connectivity to billions of devices. It will be designed specifically for the way we want to live and provide a platform on which new digital services and business models can thrive. It will enable machines to communicate without human intervention in an Internet of Things capable of driving a near-endless array of services. It will facilitate safer, more efficient, and cost-effective transport networks. It will offer improved access to medical treatment, reliably connecting patients and doctors all over the globe. From low-power, sensor-driven smart parking to holographic conference calls, 5G will enable richer, smarter, and more convenient living and working. It is a giant step forward in the global race to digitize economies and societies [14].

5G is a term being used to describe the next stage of mobile network infrastructure technology beyond 4G/ LTE. 5G will offer totally new possibilities to connect people, and things – being cars, houses, energy infrastructures. The 'anytime, anywhere, anyone and anything' capability of 5G is expected to play an important role in supporting a wider deployment of new services globally. 5G technologies makes a "truly connected world" a reality by providing unprecedented connectivity and allows the future mobile-broadband user experience radio access with "unlimited" performance. It ensures that data is accessible instantaneously and the services are delivered without being hampered by waiting times or unreliable access. 5G can unleash new economic opportunities and societal benefits giving it the potential for being a transformational force for societies across the globe.

Industry organizations, governments, consumer groups and standards bodies around the world are working to clarify and define the key characteristics of 5G.

2.5.2 Features of 5G

The main characteristics of a 5G network are expected to include lower latencies, faster network data rates and support for a massive increase in network connections. The most revolutionary characteristics which defines 5G are the near-zero latency and data rates of peak data rates of 10 Gbps. 5G can be described as a software-based communication network architecture, which can be dynamically programmed to provide the right control layer for a given application. This will facilitate new and diverse business use cases. 5G supports "network slicing", which allows a Virtual Network Operator to define its own network architecture, enabling rapid roll out of scalable services at lower costs [15].

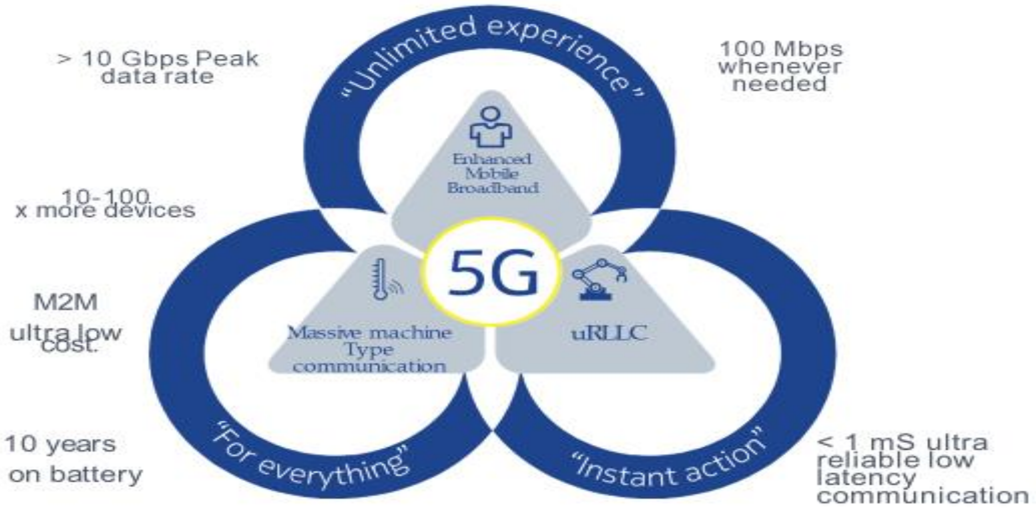

Figure 2.3: Characteristics of 5G (Source: GSMA Intelligence)

The specific requirements for 5G identified by GSMA Intelligence provide a useful framework for assessing consumer and industry demand for 5G services and potential use cases, as well as the technological developments needed to support construction of a 5G network.

The key characteristics that will be required of a network for it to be classified as a 5G network are:

- **Data rates**—10 Gb/s data rates to support ultra-high definition video and virtual reality applications. This is a step change for mobile networks and is expected to facilitate a high quality and a more seamless user experience.
- **Ultra-low latency**—reduce latency to a one millisecond end-to-end round-trip delay. This is also a step change for mobile networks. This will enable new applications in On-line gaming, Augmented reality, vehicle-to-vehicle applications.

- **Bandwidth**—provide 1000 times more bandwidth per unit area than available on existing mobile networks. This will support faster data rates and increase network capacity to support data intensive applications in both the uplink and downlink
- **Connections**—Support the growth of 10 to 100 times more connected devices than is now supported by existing networks. Will support hundreds of billions of machines and several billions of applications
- **Always on**—be available everywhere (100 per cent coverage) always (99.999 per cent of the time) giving an always-on user experience. It is necessary for high mobility applications and coverage indoors and outdoors as well as high reliability requirements for services where network outage could have catastrophic consequences.
- **Energy usage**—reduce network energy usage by 90 per cent device.
- **Battery life**—facilitate up to 10 years of battery life for low power, machine-type devices [16].

In addition, 5G should enable new diverse use cases and applications like:

- Relaxed latency requirements - Remote meter reading for billing purposes
- Strict latency requirements < 1mS - Process industry safety & control systems, real-time patient monitoring, Security & Video surveillance, real-time traffic light control, Two-way gaming, Virtual & Augmented reality etc.
- High levels of network reliability. -- Electrical grids, industrial control, eTraffic, e-health and smart-city management**.**
- Relaxed level of network reliability -- Temperature /moisture sensors @ home.
- High Volume of information -- Remote video surveillance etc
- Low volume of information - Cargo tracking in the shipping industry. Etc
- Low device cost/ low energy -- Battery powered sensor networks.

5G has several potential use cases across industry verticals. Most of these can be grouped in three main categories:

- **Enhanced mobile broadband.** (eMBB) High speeds measured in Gbps. Faster speed, lower latency, and greater capacity could enable on-the-go, ultra-high-definition video, virtual reality, and other advanced applications. Improved and uniform high throughput experience, better in building/ indoor access, capability to cater to dense/ crowded areas, improved spectrum utilisation is expected to enable deployment of data intensive use cases like Augmented and Virtual Reality (AR/VR), Cloud, 3-D Video/ 4K screens. Telcos need to monetise this opportunity would drive the adoption of 5G.

  Some of the potential use cases under this category are:

  - Real-time AR /VR services
  - Enhanced in-building broadband service
  - Crowded or dense area service
  - High definition cloud gaming

- Content streaming
- Fixed Wireless Access service.

➢ ***Ultra-Reliable and Low-Latency Communications (uRLLC***) – Ultra-reliable communications: High reliability, high availability, and low latency down to 1ms end to end. This is also called as Mission Critical Services. This 5G feature provides a highly available and reliable network. 5G has the potential to deliver significantly lower latency (to about one millisecond). This will facilitate real-time capabilities and performance to support services which require greater monitoring and control. As connected devices become increasingly central in applications that demand absolute reliability—medical devices and vehicle safety systems, for instance—latency will serve as a limiting factor. Improved reliability and ultra-low latency applications have applications across industry verticals.

Some of the potential use cases under this category are:

- Autonomous vehicles,
- Drones
- Robotic applications,
- Industrial IoT
- Health monitoring system / tele-health,
- Smart grid
- Intelligent transportation

➢ ***Massive Machine Type Communications (mMTC)*** – IoT is emerging as one of the primary use cases for 5G. There is growing awareness among companies of the transformational impact that IoT can have on their businesses, and hence the importance of 5G technology as an enabler of this process. The discussion of IoT is extending beyond applications, such as connected car and smart metering, to encompass the entire range of business activities across vertical industry sectors such as manufacturing, utilities, and the production of raw materials. Low power consumption, low cost, and the use of low-frequency spectrum bands to provide broad and in-building coverage. The explosive growth in the number of connected devices puts lot of pressure on existing 4G/LTE networks as they had limited network connectivity and reliability in dense urban areas. Also, the device power requirements limited the wide scale application IoT. The advent of 5G will unlock the potential of the Internet of Things (IoT) by enabling more connections at once (up to one million per square kilometre) at very low power. mMTC use cases can benefit new industry verticals such as to name a few

Some of the potential use cases under this category are:

- Smart cities
- Agriculture
- Energy/ utility management
- industrial automation

- Smart logistics
- Smart grids and metering
- Smart consumer wearables
- Smart surveillance and video analytics
- Smart retail

5G will offer totally new possibilities to connect people, and things – being cars, houses, energy infrastructures. 5G technologies makes a "truly connected world" a reality by providing unprecedented connectivity and allows the future mobile-broadband user experience radio access with "unlimited" performance. It ensures that data is accessible instantaneously and the services are delivered without being hampered by waiting times or unreliable access.

5G is more than just a generational step; it represents a fundamental transformation of the role that mobile technology plays in society. As demand for continuous connectivity grows, 5G is an opportunity to create an agile, purpose-built network tailored to the different needs of citizens and the economy. It is an opportunity for operators to move beyond connectivity and collaborate across sectors such as finance, transport, retail, and health to deliver new, rich services. It is an opportunity for industry, society and individuals to advance their digital ambitions, with 5G a catalyst for innovation.

2.5.3 5G Fixed Wireless Access

Fixed wireless access. Fixed wireless access (FWA) has existed for years, primarily in areas with no viable wired broadband. 5G, particularly in the millimetre wave spectrum, can deliver speeds of more than 100 Mbps to the home, making it a viable alternative to wired broadband in many markets, especially in markets without fibre. As such, 5G FWA could represent a new revenue stream for wireless operators, but typically only in areas where consumers don't already have access to fibre to the home and DOCSIS 3.0/3.1 cable broadband. Fixed Wireless Access (FWA) provides the performance of fibre offered through a wireless solution. It would be important where current fixed infrastructure is unable to provide sufficient service or there is copper/fibre infrastructure does not exist to deliver wired broadband. This eliminates the need for cable installation.

- Ericsson has reported that 5G will enable cost-efficient FWA solutions on a massive scale with 10 to 100 times more capacity than 4G networks and that it is an attractive alternative to wireline solutions [17].
- Orange Romania with Samsung and Cisco has successfully conducted FWA test in real environment conditions during June-July 2018. Samsung 5G terminals were used in buildings to provide 5G signals to Cisco Wifi routers inside homes. Trial proved successful testing of 4K video and cloud gaming [18]
- University of Sussex, UK, has completed initial testing of FWA equipment for indoor 5G coverage [19].

- Optus becomes the first operator globally to deploy Nokia's FastMile 5G indoor gateway in a live network and successfully launch a 5G Fixed Wireless Access (FWA) service using the 5G New Radio standard. Samsung and Fastweb will be conducting Italy's first 5G Fixed Wireless Access (FWA) trial to demonstrate how it could be alternative to Fibre to the home (FTTH) [20] [21].

2.5.4 5G Technology Enablers

2.5.4.1 Radio Access Network

Small Cells - Most outdoor 4G mobile network deployments are currently based on macro-cells. However, macro-cells that cover large geographical areas will struggle to deliver the dense coverage, low latency and high bandwidth required by some 5G applications. To deliver the dense coverage and high capacity network required by 5G, wireless operators are now investing in the densification of their 4G radio access network (RAN) – particularly in densely populated urban areas – by deploying small cells. Small cells, while serving a much smaller geographical area than a macro cell, increase network coverage, capacity, and quality of service.

The deployment of small cells is one way of boosting the capacity and quality of existing 4G networks while laying the foundation for commercial 5G networks and early eMBB services. Small cells boost network capacity without the need for additional spectrum, making them attractive to operators with a low spectrum holding or where spectrum is scarce. Furthermore, the industry view is that the deployment of small cells in dense urban to boost existing 4G network quality, is likely to support the anticipated high capacity requirements of 5G networks and early eMBB services.

Due to the dense coverage that small cells need to provide, small cell antennae need to be installed onto street furniture – bus shelters, lampposts, traffic lights, etc. These are often accompanied by a street cabinet to accommodate the operator radio equipment, power, and site connectivity.

Massive MIMO (multiple input, multiple output) scales up to hundreds or even thousands of antennae, increasing data rates and supporting beamforming, essential for efficient power transmission. Massive MIMO increases spectral efficiency and in conjunction with dense small cell deployment, will help operators to meet the challenging capacity requirement of 5G.

2.5.4.2 Core Network

End-to-end flexibility will be one of the defining features of 5G networks. This flexibility will result in large part from the introduction of network softwarization where the core network hardware and the software functions are separated. Network softwarization – through network functional virtualization (NFV), software defined networking (SDN), network slicing and Cloud-RAN (C-RAN) – aims to increase both the pace of innovation and the pace at which mobile networks can be transformed.

- **NFV** – replaces network functions on dedicated appliances – such as routers, load balancers, and firewalls, with virtualized instances running on commercial off-the-shelf hardware, reducing the cost of network changes and upgrades.
- **SDN** – allows the dynamic reconfiguration of network elements in real-time, enabling 5G networks to be controlled by software rather than hardware, improving network resilience, performance, and quality of service.
- **Network slicing** – permits a physical network to be separated into multiple virtual networks (logical segments) that can support different RANs or several types of services for certain customer segments, greatly reducing network construction costs by using communication channels more efficiently. Network slicing separates the 'control plane' from the 'user plane' to move the user plane functionality towards the network edge. Each slice can have its own architecture provisioning management and security that supports a particular use case. Functions such as speed, capacity, connectivity and coverage ae allocated to meet the requirements of its primary objective. The prioritization of different tasks can be performed on a software level division of the network, provided the connection has low latency and good bandwidth. The slices that occupy a single physical network are separated. This ensures that the traffic and security breached from one slice cannot interfere with another slice.

  One use case of network slicing is V2X communication in autonomous driving, where car may be sending critical data requiring low latency and passengers may be watching movie requiring high bandwidth. Network slicing is one of the main features of 5G networks used to optimize allocation of resources and increase energy efficiencies. Here, one physical network can be virtually separated into multiple radio access networks, each connecting to different services [22].
- **C-RAN** – is presented as a key disruptive technology, vital to the realization of 5G networks. It is a cloud-based radio network architecture that uses virtualization techniques combined with centralized processing units, replacing the distributed signal processing units at mobile base stations, and reducing the cost of deploying dense mobile networks based on small cells.

Edge Computing - Edge computing brings data closer to end-user devices, providing computing power with extremely low latency for demanding applications. This speed up the delivery of actionable data, cuts down on transport costs and optimizes traffic routes. edge computing is increasingly important for real-time and very latency-sensitive applications.

2.5.4.3 Backhaul and Fronthaul

Backhaul networks connect the radio network (RAN) to the core network. The ultra-high capacity, fast speeds and low latency requirements of 5G require a backhaul network capable of meeting these high demands. Fibre is often considered the most suitable type of backhaul by mobile operators due to its longevity, high capacity, high reliability, and ability to support very high capacity traffic. However, fibre network coverage is not ubiquitous in all cities where 5G is expected to launch initially – and even less so in suburban and rural areas. Building new fibre networks in these areas can often be prohibitive in terms of cost for operators. In this case, a portfolio of wireless backhaul technologies should be considered in addition to fibre, including point-to-multipoint (PMP) microwave and millimeter wave (mmWave). PMP is capable of downstream throughput of 1Gbit/s and latency of less than 1ms per hop over a 2-4 km distance. mmWave has significantly lower latency and is capable of higher throughput speeds. satellite technology in 5G. HAPS and satellite systems (including non-geostationnary constellations) can deliver very high data rates (> 100 Mbit/s – 1 Gbit/s) to complement fixed or terrestrial wireless backhaul networks outside major urban / suburban areas and can deliver video transmission to fixed locations. HAPS and satellites may be integrated with other networks rather than function as a standalone network to provide 5G, thereby augmenting the 5G service capability and addressing some of the major challenges regarding the support of multimedia traffic growth, ubiquitous coverage, machine-to-machine communications and critical telecom missions

Fronthaul is a network path between centralized radio controllers and remote radio units (RRU) of a base station function.

2.5.5 Security aspects in 5G

5G security is very important due to the large numbers of connected devices, greater use of virtualization and network slicing.

According to Cisco [23], 5G security protection should include focus on

- Threat prevention by using firewalls, access controls, intrusion detection and prevention tools.
- Behaviour based checks on endpoints to stop and fix malware.
- Monitor DNS activity
- Use packet capture, big data and ML to identify threats not spotted by basic filters.

4G networks authenticates User for network access only. A trust model with two elements, between users and networks, is formed. The authentication between user and services are not covered by the networks. 5G systems are going to be service-oriented. 5G networks builds trust model between user and network and with the vertical service providers. There is cooperation between network and service providers to carry out secure and more efficient identity management [24]. Hybrid authentication management is possible where authentication is done either by networks or by service providers or by both. When done by both, networks handle network access and service providers handle service access. Connected devices including wearables, sensors etc may not be suitable for embedded SIMs. The identity management framework looks for a combination of a unique device identity or physical identity and a service identity assigned by service provider or networks. Users can decide the device access to network and the services that they are allowed to use.

5G security standards and mechanisms are being evolved. 3GPP Security Working Group (SA3) is addressing 5G security [25]. 5G Phase 1 Security (Release 15) brings several enhancements to 4G LTE security. The main use case for 5G Phase 1 was mobile broadband. In 5G, Device and network mutual authentication is based on primary authentication mechanism, which has in-built home control which advices the home operator about the device authentication in a given network, so that the home operator can take a final decision on authentication. In 5G Phase 1, authentication happens through 5G Authentication and Key Agreement (5G-AKA) and Extensible Authentication Protocol (EAP)-AKA. Optionally, other EAP based authentication mechanisms are also allowed in 5G - for specific cases such as private network.

Authentication with data networks outside the mobile operator domain is handled by secondary authentication. Different EAP based authentication methods and associated credentials can be used.

5G Phase 1 also provides inter-operator security features. Subscriber identity is protected against active attacks by a home network public key. 5G provides adequate security for the Service based Architecture of the core network. In 5G, the base-station is logically split in central unit (CU) and distributed unit (DU) with an interface between them. Security is provided for this interface. The DUs, which are deployed at the very edge of the network, do not have access to any user data when confidentiality protection is enabled. The 5G hierarchy reflects the changes in the overall architecture and the trust model using the security principle of key separation. One main difference in 5G compared to 4G is the possibility for integrity protection of the user plane.

Going forward, 5G Phase 2 will address massive Machine Type Communication (mMTC) and Ultra-Reliable and Low Latency Communications (urLLC). mMTC relates to very large number of devices transmitting a relatively low volume of non-delay-sensitive data. These devices will be constrained in terms of battery, memory, and computation resources. So, extent of security overheads must be carefully considered. urLLC relates to services with stringent requirements for capabilities such as throughput, latency, and availability. This requires high data-rates, high battery, and computational resources. Throughput of security functions need to be considered to avoid processing delay.

2.6 Business Model Innovation

2.6.1 BMI Definitions

Business Models (BM) help to capture, visualize, understand, communicate, and share business logic [26]. They help in analysing and managing the business logic of the firm and react faster to changes in business environment. This defines the 'As is" to 'To be" model. The new business model becomes a goal to achieve and guides further operations. the business model concept can help foster innovation and increase readiness for the future through business model portfolios and simulation. Company should build a portfolio of BMs to be ready for the future. BMs should be simulated and tested.

Various practitioners of Business Models have defined BM in different ways.

Osterwalder et al. [26] has defined BM as "*A business model is a conceptual tool that contains a set of elements and their relationships and allows expressing a company's logic of earning money. It is a description of the value a company offers to one or several segments of customers and the architecture of the firm and its network of partners for creating, marketing and delivering this value and relationship capital, in order to generate profitable and sustainable revenue streams.*"
Osterwalder brings in the importance of ICT in developing BM, which he defines as interrelation between business strategy, business organisation and ICT. The company' vison and overall goals sets the business strategy of the company, which is translated into a BM.

Lindgren P, had described the seven dimensions of Business Model as follows [27]

- Value proposition -Values which a business proposes to its customers, users, employees or supplier, which can be products, services or processes ideally generating a profit to the business. However, this value need not be in terms of money. It could be knowledge dissemination, good will earned or even happiness through contribution to humanity.
- Customers or Users – Customers pay for the value directly, whereas user does not pay directly. Customers can be end consumers (B2C) or businesses (B2B). Value is derived from Users indirectly for e.g. social media users.
- Value chain functions - Activities which are required to create product, service or the process.
- Competences –Internal competencies required to perform the value chain functions, which could be technology, human resources, organisation structure and its culture.
- Network – These are partners of the business, which could consist of physical networks like internal colleagues or supply chain partners or tax auditors etc. ICT systems form part of the

digital network. Networks could also be virtual i.e they are not part of the business throughout, but come into picture as and when required only/

- Value formula -Procedure for calculating price and costs, which can be quantified in terms of money or other values. This indicates whether the business is making profit or loss.
- Relations – This hold all the above dimensions together by setting a relation amongst them. Such a relation could be channelized through our physical senses (seeing, hearing, feeling, tasting, smelling) or could be virtual.

Business Model is fully connected only when the relations can create, capture, deliver, receive, and consume the values.

Gassman O et al, describes 55 reference models patterns in their **Business Model Navigator** [28].

Lindgren P, Taran Y. et al. [29] have defined **Business Model Innovation** (BMI) as a combination of

- Radicality – which looks at a radical way a company does business
- Reach of the innovation which should answer to whom all is this new.
- Complexity where the architecture itself has been changed.

The building block for this approach answers the questions

- what do we provide? - gives the value proposition
- Who do we serve? -gives the target customers
- How do we provide it? - gives the customer relations, value chain architecture, core competencies required and partner network
- How do we make money? gives the profit formula.

The answers to these define whether the innovation is incremental or radical.

Lindgren P et al, defines the concept of **Multi Business Model Innovation (MBMI)** approach to represent business scenarios having more than one BM, where the BM framework is used for both 'as-is' and 'to-be' models [30] and further defines **Business Model Eco System (BMES)** as representing more business models from more businesses [31].

Lindgren P, has defined a concept of '**Smart City Business Model Eco System (SCBMES)**, where he shows that the Smart City concept when combined with Business Model Eco System (BMES) approach would result in better sustainable smart cities. This is because Smart city cannot be represented by one business model. There would be multiple business models which have to work together in a co-ordinated way. These BMs can be defined as consisting of the seven generic BM dimensions [32].

2.6.2 BMI Frameworks

There have been several studies on BMI frameworks.

One of the earlier frameworks focussed on developing organisational knowledge management systems for business model innovation. This was based on an information-processing model and sense-making model of knowledge management system so that sustainable competitive advantage could be achieved in increasingly dynamic and changing business conditions [33].

Deloitte Consulting described a process-oriented BMI framework having a systematic approach for implementing and assessing innovation in businesses and focussing on external and internal factors and capabilities to be exploited. This framework focussed on three dimensions - who, what, and how. Being practical in approach, this framework looked for adoptability by companies in innovating their business models [34].

Apart from defining particular core elements like target customers, value proposition and value delivery system, BMI framework could also include external factors like technology, changing customer needs, regulatory & economy, and competition, which are closely linked with the formerly mentioned core elements. Sustainability is an important factor for appropriating value from BMI and the elements should be linked to sustainability. The factors providing sustainability for incumbent companies, even when the business models are less distinctive, include size advantage, longing deep relationship formed with customers, strong physical assets controlling supply-chain, monopoly control over critical resources etc. This could also induce switching costs to existing customers deterring them to go to another supplier. Start-up firms do not have the above sustainability advantages. They must develop highly distinctive business models, which must reduce the switching costs to the customers of their larger competitors and make it extremely attractive for them to come to buy their offering. The degree of differentiation and the degree of sustainability are two dimensions forming the framework of BMI. [35].

IBM described three main types of BMI - innovating industry value chain, innovating revenue model like product/service/ pricing and innovating the enterprise focussing on partners and networks [36].

Business Model Innovation is a continuous process. Companies should keep reinventing it BM to stay afloat in an ever-changing global scenario. Johnson, Christensen, and Kagermann advise that companies should have properly articulated as to why their current BM is successfully working and continuously watch out for signals which necessitate changing the BM. They should decide on changing the BM only if the new model changes the industry or the market [37].

It is important to identify 'white spaces' growth opportunities which is identifying an entirely new customer opportunity with a completely new business model which could have the effect of changing the competitive landscape. This would be challenging as companies will have to look for entirely new opportunities which are not addressed by their current business model. Mark W Johnson has provided a ‘Four Box Model Framework’ for making an effective BM which includes Customer Value Proposition, Profit formula, Key resources that value proposition requires and the key processes needed to deliver them[38].

2.6.2.1 Integrative BMI Framework:

The above BMI frameworks define BMI in different perspectives. Wirtz BW and Daiser P, has developed an ’Integrative BMI framework’ which provides a more comprehensive and holistic picture of the elements and dimensions of various BMI discussed by predecessors. This approach integrates BMI techniques and Information processing to gather systematic information and create knowledge. It further combines the concepts of BMI Sustainability and BMI competitive advantage to achieve BMI value creation/ capture. Elements of BMI processes, moderate or radical innovation are also added. Summarizing, the integrative BMI framework provides a tool that allows them to identify and reflect on critical issues, which are important for successful BMI. In this context, it can be applied as a reference system concerning organizational and strategic aspects (e.g., structural organization, methodical and organizational development, system infrastructure, and strategic focus), as well as regarding BMI audit and controlling activities. For this purpose, the elements of the integrative BMI framework must be enriched with company-specific criteria and indicators that allow BMI evaluation and measurement. Furthermore, the integrative BMI framework can also be used in the form of a checklist since it presents important elements that must be considered for successful BMI [39].

2.6.2.2 Sustainable BMI

The rising human population, environmental changes and limitation in resources are necessitating a approach to ensure sustainable future. Businesses must play a lead role to integrate sustainability dimensions in their business models. Mainstream businesses have to re-design their business models to integrate sustainability into their businesses and new companies to design sustainable business from their inception. This is quite challenging as the business models must capture economic value and competitive advantage for itself along with providing environmental and social benefits. Sustainable BMI is defined as innovations which ensure economic value creation along with creation of a net positive impact on society and environment [40].

Organisations should look towards implementing sustainable solutions so that they remain resilient and competitive in the longer run. Sustainable business models “create customer and social value by integrating social, environmental, and business activities [41].

A sustainable business model is “a model where sustainability concepts shape the driving force of the firm and its decision making [so that] the dominant neoclassical model of the firm is transformed, rather than supplemented, by social and environmental priorities.” [42].

Sustainable BMI development could involve development of entirely new business models which is ideally suited to start-ups. Existing or incumbent companies can diversify into additional BMs or transform from one BM to another [43].

This requires a long-term perspective of looking at economic gains, as short-term profitability maybe impacted due to additional sustainability dimensions. Sustainability of business will be tested when new regulations are introduced by Governments to safeguard society and environment.
Some of the ways how sustainability can be incorporated in BM are:

- Designing products or services that can maximize material productivity and energy efficiency by generating less waste, emissions, and pollutions. Apart from giving economic gains by optimal usage of resources, they also contribute to environment and society.
- Convert existing waste streams into inputs to other areas of production, thereby converting waste into both economic and environmental value.
- Use renewables which can ensure business continuity as well as reduce environmental impact.
- Design services that consumers can pay for usage as required, rather than selling physical products which are used very minimally.
- Design product and services which ensure long-term health and wellbeing of the stakeholders, thereby satisfying societal sustenance.

2.6.2.3 Cambridge Business Model Innovation Process.

The Cambridge Business Model Innovation Process (CBMIP) is a framework developed to guide organisations' business model innovation efforts and map the necessary activities and potential challenges. This addresses the different stages of business model generation, from early conceptualisation to implementation. The framework aims at providing better guidance through the business model innovation process with its different phases and activities and to map the potential challenges of the design-implementation gap for companies. It acts as a **comprehensive guiding framework** that shows what activities and challenges are generally expected when engaging in sustainable business model innovation and also act as a **tool** to ideate/plan the different phases and identify challenges customised for the specific needs and context of the company. It comprises of 8 stages – Ideation, Concept design, Virtual prototyping, Experimenting, Detail design, Piloting, Launch and corrections. It follows a iterative way to create a range of prototypes which are refined and revised. Detail design is made after validating the concepts through experimentation through controlled simulations. Pilot runs are made in target market and finally final model is launched. Adjustments and corrections are done based on ongoing feedback. This process was successfully tested at with a start-up called Favalley. The process turned out to be far from linear in the case study. Multiple iterations and feedback loops to previous stages happened during and after the workshop. In most companies, a business model innovation process is not a singular event but will be followed by another one to address the shifting challenges and opportunities in its environment, resources, and capabilities. This process is stated to benefit companies by providing guidance related to SBMI, which in turn would enhance social, economic, and environmental value for a broader set of stakeholders [44].

2.6.2.4 Data Driven Business Model Innovation

It is generally said that "Data is the new oil", due to tremendous possibilities it can bring in the business world. Data can be mined and needs to be further processed and analysed for predicting actionable insights. Currently, we are experiencing a data explosion wherein companies are using the data that they can access to analyse consumer behaviours in spending and purchases and develop new customer insights in the consumer markets. Decisions on product types and target markets are planned based on the insights analysed through data. Going further, big data is being used in the business-to-business and business-to-government sectors also [45]. Many countries across the world are implementing Smart Cities to handle the rapidly growing urbanization effectively. Big data plays a crucial role in their successful implementation. Most of the businesses, whether small or large, are looking at ways to monetize their own big data to capture new and futuristic revenue streams. Data is considered as valuable asset for companies now. Companies are looking to identify what big data they currently have and what data they can acquire followed by planning the monetization of these assets. This gives rise to the development of data-driven business models or big data business models. Examples of large companies which have made effective use of data include Google, Facebook, Apple, Amazon, Netflix, Uber, Airbnb etc. These companies have become successful due to their business model innovation rather than their product innovation [46]. The above companies have disrupted their markets or created new markets by using innovative business models designed around internal or external data collection and performing advanced data analytics to provide an unmet customer need. Successful fashion company Zara's uses real-time analysis of trending data from third party vendors and customer spending data which they use to provide an ever-changing assortment of on-trend clothing and remain successful.

IBM innovation survey found that "organizations using big data and analytics within their innovation processes are 36% more likely to beat their competitors in terms of revenue growth and operating efficiency" [47].

According to a research conducted in 2012 at MIT, it was shown that data-driven businesses have an output and productivity that is 5–6 per cent higher than similar organizations who are not utilizing data-driven processes [48].

Big data analytics is the driving force of Marketing today. According to a research report of Selerity, more than 63% of marketers reported to have increased their spend on data-driven marketing, and around 20% of all marketing spend goes on data-driven advertising campaigns. 65% of marketing executives claim that data-driven marketing is crucial to success in a hypercompetitive global economy [49].

The challenges for developing a Data-driven BM is in extracting data, refining it and ensuring that it is utilized most effectively, which is required for not only enhancing the companies competitiveness but also the survival of the company itself. Companies must first have clarity to know what to achieve by using big data. They should then formulate the value proposition i.e plan the desired offerings and the target customers. The target customers could be businesses (B2B), Consumers(B2C), Consumers through other businesses (B2B2C) or Government (B2G). They should decide what data is required and the methods of acquiring the data. The data sources could be either self-generated, existing data, freely available data, provided by customer or acquired data. Next, they should decide on the method of processing this data to extract the true value contained within data, which could be done by descriptive analytics, predictive analytics or prescriptive analytics In increasing order of sophistication depending on the level of investments in tools and resources. Further, they should decide the methods of monetizing the offerings. The revenue model could consist of Licensing, Subscription fees, Usage fee, Product sale, Renting/ leasing, Advertising, etc depending on the offerings and the target market. The challenges faced in accomplishing the desired outcome using the data-driven BM are the quality and relevance of data and the sophistication of the analytics methods used [50].

Business Models Inc defines three categories of big data BMs based on their value proposition and customers – 'Data-as-a-Service Business Model' , 'Information-as-a-Service BM' and 'Answers-as-as Service BM" [51].

'Data as a Service' BM just provides large amounts of processed and anonymised data to customers, who then can utilize this data in whatever way they want. The target customers in this case could be solution providers who may want this data to enhance their product features or develop special applications to their end consumers. However, this model must ensure that the aggregated data is anonymized and does not infringe upon any data privacy laws of the countries involved. This model has a relatively low cost in creating market and selling and has low revenue stream. Examples of users of this model could be Government open data sites etc

Describing this business model as per the 'Seven dimensions of business models' defined by Lindgren P as described in above section 2.6.1 –

- Value proposition – "Data as a Service' -Processed, aggregated, and anonymized data to Customers to create their own solution.
- Customers or Users – Developers of Products or commercial solution providers
- Value chain functions – Data ingestion, data processing, data aggregation, data anonymization
- Competencies – Data expertise, Data analytics platforms
- Network – These could be online portals, publishers, and 3rd party data sources.
- Value formula – This could be free, or subscription based
- Relations – Online service, self-service, social -media forums etc.

'Information-as-a Service' BM

Here, the processed data are analysed, and insights are provided to the customer, who may not have the expertise/ resources for this or do not want to do it themselves The customer could use these insights for their own use or further selling an idea based on certain information. This business model is about converting data into information for customers who may pay for some customized information.

Describing this business model as per the 'Seven dimensions of business models' defined by Lindgren P as described in above section 2.6.1 –

- Value proposition – "Information- as a Service' -Processed, aggregated, anonymized data, further analysed to extract some information specifically of use to Customers.
- Customers or Users -Consumers or commercial solution providers
- Value chain functions – Data ingestion, data processing, data aggregation, data anonymization and data visualization.
- Competencies – Data expertise, Data analytics platforms, Data analysis expertise.
- Network – These could be 3rd party data sources, data analytics platform providers
- Value formula – This could be subscription based, Advertising revenues and usage fees.
- Relations – Direct Sales, Online service, self-service, etc.

'Answers-as-a-Service' BM

This provides an accurate answer to specific questions of the customers, who may need this for making an immediate decision. The company must have the ability to create real and trusted value in the answers it provides to customers, who in turn relies on this answer to take important instant decisions and hence is willing to pay a higher price for this.

Describing this business model as per the 'Seven dimensions of business models' defined by Lindgren P as described in above section 2.6.1 –

- Value proposition – “Answers- as a Service’ -Processed, aggregated, anonymized data, further analysed to extract some information specifically of use to Customers and perform analytics to provide accurate answers to specific customer’s requirements.
- Customers or Users -Consumers or 3rd party advertisers and corporate decision makers.
- Value chain functions – Data ingestion, data processing, data aggregation, data anonymization, Data analytics, data visualization, what-if scenario development, predictive analytics.
- Competencies – Data expertise, Data analytics platforms, Data analysis expertise, deep customer and market knowledge
- Network – These could be 3rd party data sources, data analytics platform providers
- Value formula – Product sales, advertising revenues
- Relations – Direct contact/connection, interactive engagement, direct sales, online service etc

Big data enables new business model innovation, with increasing shift to social and unstructured data. The business model should ensure that data is tightly integrated into the core business operations from the beginning, to harness the full potential of data. Business models should be technology driven to ensure that future market conditions and customer needs are understood by harnessing the full potential of data. This would ensure business survival in a highly competitive environment [52].

Data-driven service business models have two main elements: The first one is value creation, which is dependent on the availability of the right data in-house or acquired from outside sources. Some initial test data can be used which can be further enriched via external data collection. Next, the usage of this data has to be determined with analytics, I,e to create the objective of this data. The value capture process involves planning the conversion of this data into revenue earning service by exploring the target customers. This gives a clear target market when transforming value creation into value capture.

The second element is the creation of the revenue model to be used which should make the value proposition appealing to targeted customers, thereby ensuring business sustainability. If data is not immediately available or it cannot be processed in-house, then engaging with the right partners becomes necessary.

Minatogawa VL et al, developed an artifact to assist BMI using performance measurement indicators of a company’ business model powered by big data analytics. They successfully applied and demonstrated this for a fashion e- commerce company, thereby proving that the process of BMI can be greatly enhanced by applying big data analytics [53].

2.6.2.5 Open Innovation

New 5G capabilities and use cases will be key components and enablers for future innovation in sectors such as the medicine, manufacturing, transportation, agriculture, and several others. To seize these opportunities several elements must come together. To ensure successful innovation, it is important to engage a larger cross-industry ecosystem through open access to relevant platforms. This requires new partnerships to be formed with focus on cooperation both within different sectors, but also between industry, governments, and regulators. This brings in the importance of Open Innovation.

FOSS NJ, et al., describes the process of **Open Innovation** [54] wherein companies supplement their in-house innovation capabilities with external expertise available which could be in the form of knowledge sources, individuals or organisations having that expertise. This is important as business scenarios are changing due to globalization and speed to market requirements. Companies may not have all the resources themselves to face the global competition and the need to get the products very quickly into markets.

Gassman et al, describes that a company need to be receptive to external knowledge from partners, customers or suppliers, to create opportunities for cooperative innovation processes. This process of **"Open innovation'** opens up its solid boundaries and lets valuable knowledge flow in from the outside to enable a competitive advantage of bringing offerings faster to the market through exploitation of ideas and intellectual properties[6a]. This is also listed in the ST Gallen Business Model Navigator [55].

Bogers M, [56] states that Open innovation will play a key role in the developed economies over the next decade due to the new technological trends which will fuel innovation.

COIN™ - Tata Consultancy Services Ltd (TCS), a global IT company where the author works, had introduced a patented concept called Co-Innovation Network (COIN™) in 2006 to bring together a network of experts from the start-up, research, academia and corporate worlds on collaborative innovations for its global clients. This team identifies disruptive technologies and start-ups and facilitates collaboration with its own business units and clients. TCS's in-house Research and Innovation have worked with the COIN™ partners and have developed innovative ideas which have been transitioned into customer solutions [57]. This network provides start-ups direct access to TCS's important accounts along with introductions to venture capitalists and corporate venture capital. Around 2500 start-ups from various parts across the world are on this network supported by world's leading Universities.

2.6.2.6 Scenario based Business Modelling

Ahokangas P et al, [58} has described Scenario-based Business Modelling with four possible future scenarios in telecom market which could be impacted by 5G and the approach to build business models for those scenarios. This is a very good way of looking into future, analysing what opportunities could be opened up by 5G and the regulations, and planning for it. In the **'Eternal Today' scenario**, no change in the current situation is anticipated as regulatory policies are not expected to change. Mobile Network Operators (MNO) continue providing mobile broadband services but extend their offerings to vertical markets to specific customer segments. When regulation gets complemented with local short-term licensing, new vertical connectivity providers will emerge, and market will become very competitive leading to a scenario called '**wild west'**. They will also compete with the traditional MNOs. Content specific services will be available. This scenario will see emergence of Micro Operators bringing in some 5G use cases. Regulation becoming more friendly leads to a scenario where business will become service-centric mainly for content which could be locally provisioned and distributed. This scenario is called 'utopia' and is the most preferred future scenario which could see emergence of consumers becoming prosumers and more action by Micro Operators. The last scenario, called MNOs Law and Order, will see the market situation becoming static and regulations promoting sharing of various resources such as spectrum and infrastructure. This scenario can see content service provider taking the centre stage with MNOs acting just as pipe providers or it can see the MNO controlling the business and services.

They have further used the building blocks of the 4C business model typology- connectivity, content, context, commerce and explored the kind of value which can be created and captured in each of the four layers.

2.7 Current State of 5G Global Deployment

Competition is fierce on the 5G global stage. Globally, 5G activity is growing at a very rapid pace, as vendors and service providers in technology-focused countries work on early 5G Network trials and test 5G with friendly users. South Korea, China, Japan and America are the four countries most likely to have the earliest and biggest 5G debuts. Although 2019 to 2020 is a likely timeframe for the first commercial 5G network, some countries are looking to jump off the starting block early as 2018 [59]. India is also racing fast to be first in 5G deployment.

2.7.1 Standardization, Spectrum and Regulation policies for 5G

The standardization activities related to 5G, deployment roadmap along with spectrum regulation policies are discussed here.

2.7.1.1 Standardization activities

Key research institutes and industry bodies are engaged in 5G. Few of them are:

- 5G PPP
- ITU-R
- IMT 2020- 5G
- Korea 5G Forum
- 5G Innovation Centre at University of Surrey

European Union (EU) started 5G Standardisation initiative in Nov 2012 by setting up a Society called METIS (***M***obile and wireless communications ***E***nablers for the ***T***wenty-twenty (2020) ***I***nformation ***S***ociety). METIS was a consortium of 29 partners spanning telecommunications manufacturers, network operators, the automotive industry and academia. The partners included Ericsson, Alcatel-Lucent, Deutsche Telekom, NTT DOCOMO, Nokia Corporation, Nokia Siemens Networks, France Telecom-Orange, Huawei Technologies, Telecom Italia, BMW Group Research & Technology, Fraunhofer-Gesellschaft and many other reputed Universities [60].

METIS played an important role of building consensus among other external major stakeholders prior to global standardization activities. The activities ended in June 2015.

METIS has outlined the following 5G scenarios that reflect the future challenges and will serve as guidance for further work**:** [60]

1. "Amazingly fast", focusing on high data-rates for future mobile broadband users,
2. "Great service in a crowd", focusing on mobile broadband access even in very crowded areas and conditions,
3. "Ubiquitous things communicating", focusing on efficient handling of a very large number of devices with widely varying requirements,
4. "Best experience follows you", focusing on delivering high levels of user experience to mobile end users, and
5. "Super real-time and reliable connections", focusing on new applications and use cases with stringent requirements on latency and reliability.

METIS has derived a challenging set of requirements from these scenarios, which can be summarized as: [60]

- Ten to one hundred times higher typical user data rate where in a dense urban environment the typical user data rate will range from one to ten Gbps,
- One thousand times more mobile data per area (per user) where the volume per area (per user) will be over 100 Gbps/km2 (resp. 500 Gbyte/user/month),
- Ten to one hundred times more connected devices,

- Ten times longer battery life for low-power massive machine communications where machines such as sensors or pagers will have a battery life of a decade,
- Support of ultra-fast application response times (e.g. for tactile internet) where the end-to-end latency will be less than 5 mS with high reliability, and
- A key challenge will be to fulfil the previous requirements under a similar cost and energy dissipation per area as in today's cellular systems.

The initiative continued as METIS-II in Sep 2015.

The METIS-II project will build upon METIS and other ongoing projects related to 5G but go significantly beyond the achievements in these projects. The METIS-II project will pursue the following ambitious objectives:

- Develop the overall 5G radio access network (RAN) design (where 5G refers to the overall future wireless communications system including evolved legacy and novel radio access technologies), in a level of detail in between "Technology Readiness Level 2" and "Technology Readiness Level 3" and focusing particularly on designing the technology for an efficient integration of legacy and novel radio access network concepts into one holistic 5G system.
- Provide the 5G collaboration framework within 5G-PPP for a common evaluation of 5G radio access network concepts from both a performance and techno-economical perspective. More specifically, METIS-II will further refine 5G scenarios, requirements and KPIs, develop a performance and techno-economical evaluation framework, and provide consolidation and guidance to other 5G-PPP projects on spectrum and overall 5G radio access network design aspects. Further, METIS-II will develop an open-source 5G evaluation and visualisation tool for illustrating the key use cases of a 5G system as such, and the benefit of the key radio access network design elements developed.
- Prepare concerted action towards regulatory and standardisation bodies for an efficient standardisation, development and economically attractive roll-out of 5Gwith a strong European footprint and head start.

To achieve its objectives, METIS-II will build strongly upon currently ongoing FP7 projects such as METIS, 5GNOW, MiWaveS etc. and work in close collaboration with other 5G-PPP projects. In particular, METIS-II will not perform in-depth research on physical layer aspects or on communications use cases, but rather build upon corresponding concepts from other projects and design the technology needed for the harmonization and integration of these concepts into a holistic 5G system, considering all aspects related to the user and control plane of the 5G architecture. As METIS-II is focusing on the radio access network design, it will collaborate with other 5G-PPP projects when working on technology components that are tightly related to core network aspects [60].

The 5G Infrastructure Public Private Partnership (5G PPP) is a joint initiative between the European Commission and European ICT industry (ICT manufacturers, telecommunications operators, service providers, SMEs and researcher Institutions). The 5G-PPP is now in its second phase where 21 new projects were launched in Brussels in June 2017. The 5G PPP will deliver solutions, architectures, technologies and standards for the ubiquitous next generation communication infrastructures of the coming decade. The challenge for the 5G Public Private Partnership (5G PPP) is to secure Europe's leadership in the areas where Europe is strong or where there is potential for creating new markets such as smart cities, e-health, intelligent transport, education or entertainment & media. The 5G PPP initiative will reinforce the European industry to successfully compete on global markets and open innovation opportunities. It will "open a platform that helps us reach our common goal to maintain and strengthen the global technological lead" [61].

The key challenges for the 5G Infrastructure PPP are:

1. Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010
2. Saving up to 90% of energy per service provided. The main focus will be in mobile communication networks where the dominating energy consumption comes from the radio access network
3. Reducing the average service creation time cycle from 90 hours to 90 minutes
4. Creating a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision
5. Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people
6. Ensuring for everyone and everywhere the access to a wider panel of services and applications at lower cost

In India, 5G Standardization activity started on 1 Sep 2014 by an initiative of the Global ICT Standardization Forum of India (GISFI), where it recommended a WISDOM (Wireless Innovative System for Dynamic Operating Mega Communications) based approach for defining Indian 5G. GISFI announced India specific 5G (WISDOM) standardisation plan with potential India specific requirements for

- User Perspective
- Inclusive Growth (in rural areas, e-Health, e-Education, Indian languages, ...)
- Societal Perspective (virtual family, security, ...)
- Inclusion of all Indian network initiatives (e.g. Digital India, Rail, Defence - lower bandwidth for longer distance coverage)

GISFI planned to collaborate with global Standardisation bodies like ARIB, NICT, TTA (Japan), IEEE-SA etc and Indian Government and academic institutions [62]. Currently, TSDSI has been created as the Telecom Standardization body of India and is working on 5G [63].

The 3rd Generation Partnership Project (3GPP) is a mobile communication industry collaboration that organises and manages the standards and development of mobile communications standards. It develops standards for many of the mobile communications standards from GSM through UMTS and LTE to 5G now. It is leading this effort with an active and aggressive participation by more than 550 individual member companies. 3GPP has declared its first 5G NR spec complete. The primary focus for the completed 3GPP Release 15 5G NR NSA standard is enhanced mobile broadband (eMBB) services, as well as establishing the foundation for the 5G NR design to support the future evolution. Further work in 3GPP will continue to make the specifications ready for implementation of commercial products and services.

5G NR eMBB is just a beginning for the 5G journey. 3GPP has begun preparing for work in 3GPP Release 16 and beyond. 5G NR will continue to evolve and expand. The road map of 5G NR technologies coming in Release 16 and beyond spans from ultrareliable low-latency communications, to the use of unlicensed and new spectrum sharing paradigms, to vehicle communications for autonomous driving use cases to the continued evolution of the 3GPP low-power wide-area technologies. Various study and work items have already been approved in 3GPP to define the next phase, and others will be approved in the coming months [64].

5G evolution or deployment would be in a phased manner as below: [65]

Phase 1 – In this phase, enhanced Mobile Broadband (eMBB) services would be implemented. FWA and mobile services expected to be implemented by 2020. It is expected that by many countries would have deployed 5G broadband services by 2021.

Phase 2 – Massive Machine Type Communications (mMTC) services would be implemented. 5G based IoT technology would be expected in 2021. The entry of 5G IoT will accelerate the earlier deployment of smaller IoT networks built around NB-IoT and LoRa.

Phase 3 – Ultra reliable low latency communication (uRLLC) services are expected in 2022 which would see deployment of use cases like drones, remote machine control, intelligent transportation, robotic surgery etc.

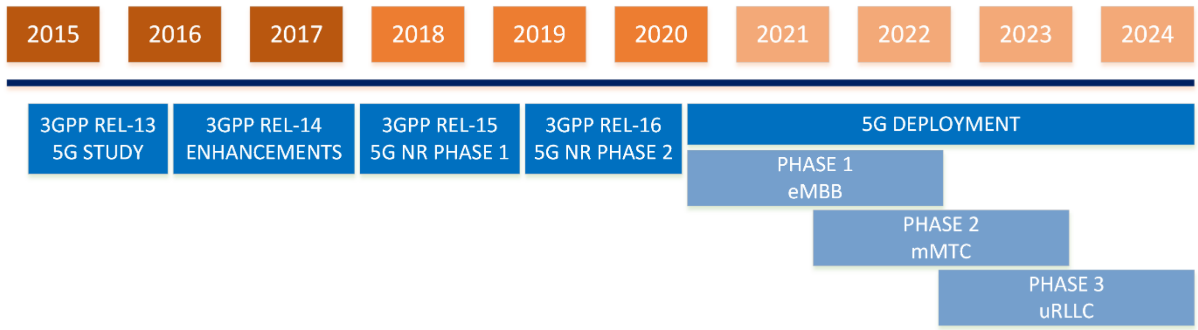

Figure 2.4: 5G Standardization and Deployment roadmap

2.7.1.2 Spectrum regulation Policies

Radio spectrum is a scarce resource, and spectrum policy is key to enable cost effective and quality wireless services. 5G applications have different spectrum requirements in terms of frequency range (low, high) and size (wide, ultrawide). Methodology for arriving at spectrum needs, requires consideration of multi-operator deployment environments, inter- and intra-network interference considerations, frequency reuse, need for multiple carriers and radio interface capabilities. Continued growth of data and video demands more spectrum. Variety of spectrum is needed for different use cases [66].

High Level Requirement	Spectrum requirements
mMTC type services and high mobility eMBB broadband services – good radio coverage	Below 1 Ghz
Ground/ obstacle penetration	Below 1 Ghz
Flexible transition from 4G LTE to 5G	Below 6 Ghz
eMBB and uRLLC tyoe services – Wider spectrum availability - Reduced coverage	1 to 6 GhZ
New technologies enable use of higher bands	> 6Ghz
Important for propagation / RF	6 Ghz to 30 Ghz
Easier access to wider channels	> 30 Ghz
Low mobility and FWA services – Higher spectrum and limited coverage	24 Ghz to 41 Ghz

Table 2.2: Spectrum requirements for 5G use cases and services

World radiocommunication conferences (WRC) are held every three to four years. WRC reviews and if necessary, revises the radio regulations which is the international treaty governing the use of the radio-frequency spectrum and the geostationary-satellite and non-geostationary-satellite orbits. Revisions are made based on an agenda determined by the ITU Council which considers recommendations made by previous world radiocommunication conferences. The general scope of the agenda of world radiocommunication conferences is established four to six years in advance, with the final agenda set by the ITU Council two years before the conference, with the concurrence of most member States. Last WRC -15 happened in 2015, where it was decided which 5G spectrum should be studied and considered for identification at WRC-19, which is happening at Egypt during end of 2019.
A variety of bands is needed to address both coverage and capacity needs of evolved 4G and 5G systems. Frequencies beyond those traditionally used for cellular systems, especially those above 6 GHz are important to consider. While the lower frequencies have better propagation characteristics for better coverage and thus can support both macro and small cell deployments, higher frequencies can support wider bandwidth carriers (due to large spectrum availability at mm-wave bands) for providing very high peak data rates in specific areas where traffic demands are very high.

Different licensing aspects of 5G spectrum are: [65]

- Licensed -- Regulator granting exclusive right to an operator. This provides reliable, secured spectrum for predictable quality/capacity and is critical part of 5G deployments.
- Unlicensed - No registration or individual permission are required. Rules are established to avoid interference. It complements for 5G, e.g. in small cell deployment.

- Shared with incumbents. This leads to coordinated access when/where not used by incumbents. It facilitates timely access to spectrum in shared bands.

Regulatory frameworks for the available mobile communication bands need to be reviewed and new frameworks need to be established for 5G NR deployment in new frequency bands. These frameworks should facilitate innovation by removing any potential barriers to the introductions of key 5G innovations. For example, regulatory frameworks should embrace the principle of technology and service neutrality for the smooth introduction of the latest available technologies and services in existing and new bands that will be made available for 5G.

2.7.2 Readiness of Technology Providers

Standardization of 5G is underway. However, leading equipment vendors, chipset manufacturers and telecom operators across the world have invested huge amount so money in 5G readiness and trials are underway, with announcements being made on launch dates. The author has also described this in the section 2.7.2 through 2.7.8 addressing 5G deployment across the world.

The author discusses the initiatives and collaboration of leading 5G technology providers like Ericsson, Nokia, Samsung and Huawei in sub sections 2.7.2.1 through 2.7.2.4. [20],[21], [67].

2.7.2.1 ERICSSON (Sweden)

Ericsson is the only vendor having 5G presence in all the continents. Their 5G radio protypes was one the earliest products designed to enable operators to conduct live field trials. Ericsson design ensures smooth transition from 4G to 5G, which brings increased flexibility for spectrum asset usage since it enables to deploy both 4G and 5G in the same spectrum. Their design handles indoor coverage. A street macro solution and RAN compute portfolio has been announced for launch in the second half of 2019. Many telecom operators collaborate with Ericsson and have done trials.

Some of the recent 5G deployment contracts won by Ericsson includes:

- A multi-year contract from US Cellular for 5G network deployment to provide 5G NR hardware and software
- From Etisalat to deploy 5G network in UAE.
- From Saudi Telecom Company (STC) to launch 5G network in Saudi Arabia
- From Telenor group to transform its core network in Sweden, Denmark and Norway.
- From Telstra for 5G network rollout in Australia
- From Bharati Airtel for 5G in India
- From Movistar to deploy 5G in Argentina
- From BSNL in India to develop new 5G use cases.
- From Ooredoo, Qatar to make its network fully 5G enabled across Qatar.

Some of the recent 5G trials conducted with Ericsson include:

- Korea Telecom, Ericsson and Intel conducted a connected vehicle 5G trial streaming 4K video, during Feb 2019.
- Ericsson showcased the first-ever live 5G demonstration in India. The demonstration using Ericsson's 5G test bed and 5G New Radio (NR) delivered a throughput of 5.7 Gbps and ultra-low latency of 3 millisecond.
- Ericsson with Telia and Einride demonstrated driverless truck based on 5G connectivity, in Sweden
- Along with SK Telecom and BMW, demonstrated connected car travelling at 170 km/hour.
- Conducted Bahrain's first 5G trails with Batelco to demonstrate 5G capabilities in a real-world environment.

2.7.2.2 NOKIA (Finland)

Nokia looks at 5G for its future growth. The result of Nokia 5G maturity index announced at MWC 2019, revealed that two-thirds of operators expect 5G to create new revenue streams while more 70% are focussed on 5G to improve existing consumer services. Nokia has setup a project called "5G MoNArch" along with Deutsche Telekom in an 8000-hectare campus to trial 5G in a real-world environment. Nokia has started manufacturing 5G NR equipment at Chennai, India.

Some of the recent 5G deployment contracts won by Nokia includes:

- From Optus to establish first 5G commercial services in Australia. Optus becomes the first operator globally to deploy Nokia's FastMile 5G indoor gateway in a live network and successfully launch a 5G Fixed Wireless Access (FWA) service using the 5G New Radio standard.
- From T-Mobile to accelerate deployment of a nationwide 5G network.
- From Sandvik to deliver industrial IoT to mining industry.
- From Telia to build a network called '5G Finland' which is open to all Finnish companies and organisations.
- From China Unicom to prepare its network for evolution to 5G technology.
- From China Mobile to explore applications of 5G in areas like smart cities, smart transportation and intelligent video analytics.

Some of the recent 5G trials conducted with Nokia include:

- During MWC 2019, Nokia along with Vodafone demonstrated massive MIMO innovations to improve 5G capacity and performance.
- They signed MoU with Korea Telecom during MWC 2019, to trial NFV and network slicing.
- Built a 'Early 5G innovation cluster' with Telefonica to test and measure the performance and coverage of first 5G services in a dense urban area.

- Along with France Televisions, Showcased world's first UHD TV streaming in real conditions over 5G.

2.7.2.3 SAMSUNG (S.Korea)

Samsung exhibited its new Galaxy S10 5G mobile phone on 24 Feb 2019. It acquired an AI based company to further enhance its 5G capabilities. In Feb 2018, Samsung had developed the world's first complete commercial 5G FWA solutions.

Some of the recent 5G trials conducted by Samsung include:

- Samsung along with Orange and Cisco, showcased two industrial 5G applications in MWC 2019- Industrial robot and drone.
- Samsung and Fastweb will be conducting Italy's first 5G Fixed Wireless Access (FWA) trial to demonstrate how it could be alternative to Fiber to the home (FTTH).
- Samsung along with KDDI has successfully completed a 5G test with real time transmission of 4K UHD surveillance video on a train platform, which is the first in Japan.
- Partnered with Telefonica Deutschland to conduct FWA trial in Germany.
- Partnered with Russia's MTS to successfully demonstrate 5G solutions including HD video calls, ultra-low latency video games and HD streaming.
- Partnered with KDDI to successfully demonstrate real-time video streaming test during a professional baseball game held in Japan.
- In December 2017, it had partnered with KDDI to demonstrate 5G in a moving train.

Some of the recent 5G deployment contracts won by Samsung includes:

- From Korea Transportation Safety Authority to build 5G and Vehicle-to-Everything (V2X) network at K-City, which is a testbed for autonomous driving in Korea.
- From SK Telecom to supply 5G solutions.
- From Verizon to provide 5G broadband internet service to consumers in California and few other parts of US.
- From AT&T to supply 5G ready Citizens Broadband Radio Service network.

2.7.2.4 Huawei (China)

Huawei plans to launch a full range of commercial equipment including wireless access networks, core networks and devices. They have been very aggressive in 5G development and holds a good percentage of patents essential for 5G networks. AI is an integral element of Huawei's 5G strategy.

During MWC 2019, they launched the world's first commercial 5G CPE supporting 3GPP standard using their own 5G chipset. They have also designed their own chip for 5G base stations. They introduced first 5G enabled foldable smartphone at MWC 2019.

Of late, many countries have banned Huawei from entering into their country's networks citing security concerns. These include US, Australia, Canada etc.

Some of the recent 5G trials conducted by Huawei include:

- They completed the 5G NR test in a 5G trial organized by IMT-2020 (5G) Promotion Group in Jan 2019.
- Installed three 5G base stations in Tibet
- 5G trial in South Africa with MTN
- Successfully completed 5G NR interoperability and development testing, along with Qualcomm
- Conducted a connected vehicle demo at MWC 2019 along with Vodafone.
- Currently, carrying out a demo of 'cloud-based 5G end-to-end network slicing', in partnership with Deutsche Telekom.

Some of the recent 5G deployment contracts won by Huawei include:

- Deployment of 5G infrastructure at Saudi Arabia.
- Deployment of 5G networks in Malaysia with Maxis.
- Shanghai mobile has contracted Huawei to complete the world's first Real 4H HDD live broadcasting through 5G network slicing.

2.7.3 Current 5G Deployment scenario in Asia

2.7.3.1 South Korea

Two service providers in South Korea. SK Telecom (SKT) and Korea Telecom(KT) are vying to be first to market with a 5G network. SK Telecom has acquired spectrum in the 3.5 GHz and 28 GHz frequencies in anticipation of deploying 5G and has established a 200-member task force aimed at competing rivals KT and LG Plus in the launch of 5G services.

KT had rolled out a trial 5G network in 2018 Winter Olympics in Seoul, expected to cover events in few cities. 5G service allowed athletes and visitors to experience 5G-dependent services including time slice video streaming, as well as 360-degree VR video. The trial equipment deployed for the games is aligned with the first 5G new radio specifications ratified by the 3GPP in December 2017, so KT should be able to incorporate it into its 5G rollout. This trial was a success. Based on this, KT has planned to commence commercial 5G operations in March 2019. They plan to be one of the first operators in the world to commercially launch 5G mobile services next year. Their goal is to build a nationwide 5G infrastructure to guarantee coverage. They have ruled out launching fixed wireless access based on 5G for now. KT is looking at possible 5G business cases to commit a large-scale investment in 5G.

South Korea's Ministry of Science and ICT is aiming to hold 5G auction in June 2018. The ministry has asked the nations operators (SK Telecom, KT, LG Plus) to accelerate adoption of 5G Technology [68].

2.7.3.2 China

China is also expected to be a fast mover in 5G. GSMA estimates that by 2025 China will represent 40 percent of global 5G connections. According to a study from the China Academy of Information and Communications Technology, the research arm of the Ministry of Industry and Information Technology (MIIT), 5G could account for 3.2 percent of China's entire GDP in 2025, generate 8 million jobs, and add 2.9 trillion yuan in economic value by 2030. China expects a huge increase in the number of new companies, employment opportunities, and equipment sales.

China Mobile Hong Kong has started a 5G technologies Open Lab in preparation for a trial launch on mid-2018. This lab will act as a testbed for its partners to develop new use cases and will collaborate with local universities. They are using 5G equipment based on 3GPP 5G NR standard. China Mobile plans to build 12 such Open Labs. They are working with 112 partners in areas of IoT, Internet of Vehicles and AR/VR [69].

2.7.3.3 Japan

NTT DoCoMo demonstrated an advanced security service trial based on 5G networks with the view of handling security for the opening ceremonies of the 2020 Olympics. The trial included is of drone with HD 4K camera and AI [70].

NTT Docomo has conducted several 5G trials with Chinese vendor Huawei. However, NTT DoCoMo has signed up with NOKIA for 5G equipments for future commercial launch. Another Japanese telco Softbank is partnered with Huawei for trials and demonstrations of 5G use cases for enterprise business. They plan to launch 5G commercial services around 2020. They have also been working with Ericsson for conducting trials. KDDI has also been doing trials with Ericsson in Japan to test a range of use cases and interworking between 5G and LTE technologies [71].

NTT DoCoMo plan to launch pre-commercial 5G services in Sept 2019 and official launch in 2020 [72].

2.7.4 Current 5G Deployment scenario in Europe

Europe was the leader in earlier planning of 5G. European technology OEM like Ericsson and Nokia are very well advanced in the standards and design of 5G equipment.

2.7.4.1 5G Deployment scenario in UK

UK Government has awarded a contract of £25 million to several high-tech organisations, with the aim of making the UK a world leader in 5G. The six companies and organisations who successfully won contracts to trial and test 5G across a range of applications are:

- Cisco Grant: £4.3m
- West of England Combined Authority Grant: £5.0m

- Worcestershire Local Enterprise Partnership Grant: £4.8m
- Sensor City Grant: £3.5m
- Airspan Communications Ltd Grant: £4.1m
- Quickline Communications Grant: £2.1m

The primary work involves the installation of a fully functional 5G testbed at six locations for use by organisations, and in some cases the public, to test and validate applications and hardware [73].

The work will cover:

- Smart farming via the use of drones
- Health care in the home via the Internet of Things (IOT)
- Cyber security
- Increasing manufacturing productivity
- Enhanced visual experiences for tourists
- Patient care and monitoring
- Self-driving cars

The winning bidders and their projects involve setting up testbeds across the UK in the following locations each with its own project brief as follows:

- Cisco Grant Project**:** The project is named 5G Rural First and will look at smart farming, autonomous farm vehicles and remote veterinary inspections.
- West of England Combined Authority Grant: This project is named 5G Smart Tourism and will focus on delivering enhanced visual experiences for tourists via Augmented Reality (AR) and Virtual Reality (VR) technology.
- Worcestershire 5G Consortium: Malvern Hills Science Park -industrial productivity robotics, cyber security, big data analytics and Augmented Reality over 5G.
- Sensor City Grant: - public sector health suppliers, the NHS, university researchers etc. The focus here will be in patient care and monitoring, loneliness in older adults and communication between hospitals and the community.
- Airspan Communications Ltd Grant: - Development and validation of connected and autonomous vehicles. The focus for this project covers complicated cell-tower handoffs, and autonomous vehicles network bandwidth issues and how 5G connectivity solutions could be transferable to both road and rail transportation.
- Project run by Quickline Communications Grant: This project is named the 5G Rural Integrated Testbed (5GRIT) and will be used to trial and test smart agriculture, 5G-ready AR apps for tourists and connecting poorly served communities.

UK 5G Innovation Network [74]

The UK5G innovation network objective is to unify the UK's fledgling 5G industry and to help ensure that the country is a front-runner in 5G development. UK5G is the name that has been chosen to represent a consortium incorporating Cambridge Wireless (lead), Knowledge Transfer Network and TM Forum. They will also provide feedback to the UK government's 5G Testbeds and Trials Programme, advising on future areas of focus and identifying priorities.

5G TRIALS

The first 5G trial happened in Bristol during 2018. This is a first live 5G public trial carried out by the University of Bristol, British Telecom and Nokia. This trial demonstrated Massive MIMO radio access solutions (combining multiple antennas to improve the capacity of the network), software-defined networking, network slicing (splitting a single physical network into multiple virtual networks) and edge computing nodes functionalities [75]. More recently Samsung and Arqiva teamed up to launch the UK's first 5G Fixed Wireless Access (FWA) field trial.

UK's largest network operator, EE, plans to launch 5G in 2019 and cover all areas by 2020. They will offer OnePlus 5G smartphone. Vodafone UK is starting 1000 5G testing sites in 2019. O2 plans to roll out its 5G in 2019. CItyFibre and Arqiva are creating a 5G ready network platform nationwide that will provide the best network at the best economics for MNOs. Three UK have tested 5G for home use.

2.7.4.2 5G Deployment scenario in Finland

a) '5G Test Network (5GTN) Finland' is a consortium of OEM (Nokia}, MNOs (Telia, Elisa) and academia (Oulu, Aalto, Turku.) with an objective of providing the best 5G test network environment and ecosystem. Test networks are crucial to support development of applications. 5G test network is developed and deployed in Oulu, Finland and provides extensive test facilities in a carrier grade state of the art network, to support application developers. The setup demonstrates 5G and IoT convergence. The full demonstration set-up uses 5GTN and Korean Koren assets and provides connectivity between Finland and Kores to support 360o video with IoT sensors and actuators with 5G backhauling in conjunction with 208 Korean winter Olympics. [76] [77].

b) Elisa Oyi Telecommunications launched commercial network in Tampere and Tallinn in Jun 2018 and is claimed to be the first in world to launch commercial 5G, as per their website [78]. They made the world's first video call to Estonia on a 5G network. They have offered a 5G ready plan for Euro 44.0 per month for unlimited 5G data with speeds upwards of 600 Mbps. They have also announced that they will automatically upgrade existing subscription to 5G when customers have access to 5G networks.

c) Telia had made a pre-commercial 5G launch and Helsinki airport became the first 5G airport in the world in December 2018. Telia launched commercial use of its 5G network in 3 cities of Finland during early 2019. They will be testing 5G Fixed Wireless Access (FWA) later.

d) Another Telecom operator, DNA, has announced that they will launch 5G in Helsinki in early 2019, to cover the entire city. They are starting a fixed wireless access network in Vantaa.

2.7.4.3 5G Deployment scenario in Norway

a) Telenor, the largest telecon operator plans to launch 5G in Norway in 2020. They have successfully tested 5G in early 2017 and launched three 5G base stations in Kongsberg during November 2018 and plan to run a 5G pilot there.
b) Telia opened its first 5G test network in Dec 2018. Their plan is to develop 5G -based solutions industry by industry and area by area. They have partnered with Norwegian ISP GET to launch 5G pilot in Smart Homes.

2.7.4.4 5G Deployment scenario in Sweden

Telia is planning a commercial launch in Sweden in 2020. They launched a 5G testbed in Stockholm during December 2018, with collaboration with Ericsson, to experiment with 5G use cases. In early 2019, they launched a 5G network with collaboration with Ericsson and Volvo, to showcase Industries 4.0

2.7.4.5 5G Deployment scenario in Germany

Government has released a '5G strategy for Germany' document which states that trails began in 2018 and expected commercial launch is 2020 with a planned rollout over 2020 to 2025.

a) Deutsche Telekom has deployed Europe's first 5G antennae. They plan to install 2000 new mobile base stations in 2019 and cover 90% of the country with 5G by 2025.
b) Telefonica Germany built their 'Early 5G Innovation Cluster' with Nokia during December 2018. This will be used to measure the performance and coverage of first 5G services in a dense urban area.

2.7.4.6 5G Deployment scenario in Switzerland

a) Swisscom, the largest operator in Switzerland, successfully completed a data transfer trial in November 2018 in collaboration with Ericsson and Qualcomm. The trial involved a 5G smartphone prototype which connected to a live 5G network. They anticipate 5G coverage throughout the Swiss territory in 2020 as 5G ready phones are expected to appear on the global market in early 2019.
b) Sunrise, the second largest operator in Swiss, is bringing 5G to 50 to 150 cities and villages by end of March 2019. They successfully ran their 5G test in 2017 and made their first standardized 5G network at a ski resort in November 2018
c) Salt (formerly Orange communications) have partnered with Nokia to provide 5G services.

2.7.4.7 5G Deployment scenario in Russia

a) Russia's largest mobile operator, MTS, has partnered with Samsung to in testing 5G use cases which included video calls, ultra-low latency video games and 4K video streaming.

b) Tele2Russia announced that they would deploy 50,000 base stations in Russia in collaboration with Ericsson.

2.7.5 Current 5G Deployment scenario in Americas

The Telecom Service Providers in the 5G race are AT&T, Verizon, Sprint and T-Mobile.

AT&T has contributed to the first phase of 5G standards, conducted multi-city trials and transformed network for the future and would be delivering standards based mobile 5G. Initial mobile 5G deployments this year will be based on 3GPP standards. AT&T is opening a new 5G lab where Engineers can build and test creative solutions and run stress tests with mobile 5G network equipment and devices from multiple vendors before they are rolled out to customers. This lab is also equipped with an outdoor 5G testbed to trial a variety of 5G applications and real-world use cases [79].

AT&T is aggressively expanding 5G services in over 20 markets by the end of 2017. The company is also conducting trials of DIRECTV Now over fixed 5G wireless in Indianapolis and Austin. The tests in Austin resulted in a download speed of 1 Gbps (gigabit per second), which is much better than the currently available standard 4G LTE network. AT&T competes with Verizon and T-Mobile in 5G market, by buying Spectrum worth $ 18.2 Billion as against $10.4 Billion by Verizon and $1.8 Billion by T-Mobile [80].

AT&T has planned to launch a standards-based mobile 5G service in a dozen cities in the United States before the end of 2018. They will offer a mobile "puck" device in time for the launch as 5G smartphones are not expected to hit the market until 2019.

Verizon has planned to launch a fixed 5G service in three to five cities in 2018 and expects to launch a mobile 5G service soon thereafter. They would eventually have to replace its proprietary V5GTF 5G equipment with 5G equipment that adheres to the 3GPP's 5G standard after it launches its initial fixed wireless markets.

Sprint has said it will launch mobile 5G services on its 2.5 GHz spectrum holdings on a nationwide basis in the first half of 2019 [81]. T-Mobile plans on conducting a nationwide mobile 5G launch starting in 2019 and finishing in 2020. Ericsson and Nokia are their OEM vendors.

T-Mobile wants to deliver a truly transformative 5G experience, which works on smartphones and not on "pucks" s planned by AT&T. They are continuing their development on advanced LTE networks leading to 5G, as the first 5G smartphones will use both 5G and LTE simultaneously. Currently, phones must choose between 2G, 3G, or 4G LTE and use one at a time. The combination of 5G and LTE means way faster speeds, and that's why T-Mobile is not letting up on its LTE developments [82].

2.7.6 Current 5G Deployment scenario in Australia

The major Mobile Telecom Service Providers in Australia are Telstra and Optus.

Telstra is expected to launch its 5G network in 2019. It will run extensive 5G trials on the Gold Coast during the Commonwealth games in April 2018. Optus was the first Australian Telco to announce it would go to market with 5G offering in 2019. It said that it would start the roll out by deploying 5G fixed-wireless internet to metropolitan areas and that the new service would offer 15 times faster than the current technologies. It had also earlier announced that it was investing $ 1 billion to upgrade its regional mobile network. It had recently launched an outdoor trial for 5G New Radio and is set to showcase the technology at 2018 Gold Coast Commonwealth games including trials of its mobile network [83].

Telstra has recently launched the world's first public 5G hot spot, in Australia's Gold Coast. However, as there are currently no commercially available 5G devices on the market, Telstra has utilised WiFi technology to allow users to experience 5G like download speeds. By connecting 5G backhaul and infrastructure to a WiFi access point, Telstra can give consumers a taste of 5G.

The 5G hotspots will be open to anyone in the Gold Coast area and will be free to use with a download limit of 10 GB per day per device [84].

2.7.7 Current 5G Deployment scenario in India

Government of India has constituted a "High Level Forum for 5G India 2020" on 22 Sep 2017, with an objective to position India as a globally synchronised participant in the design, development and manufacturing of 5G based technology, products and applications. This forum is formed with members representing very senior people from Dept of Telecom and Industry. The mandate of this forum is to finalise report on 5G Vision, Mission and Goals by March 2018 and further evaluate and approve roadmaps/ action plans for 5G India 2020 [85].

The full 5G roadmap is expected to be ready by 2018. Meanwhile, the telecom industry maintained that they have the ecosystem in place for 5G but the first step of 5G would be taken with spectrum allocation. The 5G spectrum will only be available in the 3300 MHz and 3400 Mhz band [86].

The major Telco, Bharti Airtel, has announced that it will be piloting 5G capabilities pan-India starting with Indian Premier League cricket matches from 7th April 2018. They have already begun testing 5G in Bangalore and tested the same at Mobile World Congress, Barcelona. For the IPL matches, they will be setting up MIMO, WIFI devices across the stadium in 10 cities where matches are played. Visitors in the stadium will get enhanced internet speeds [87].

Bharti Airtel has begun work on identifying use cases around 5G while conducting technology lab test trials in the country. The telco is also making efforts to leverage software-defined networking and network functions virtualization technology to optimise networks and launch new services as part of its strategy to transform into a digital telco. The telco will use its new digital innovation lab in Bengaluru to explore these 5G use cases with the help of start-ups and technology companies. The lab will work on emerging technologies such as Artificial Intelligence, the Internet of Things, Augmented Reality and Virtual Reality as part of its broader strategy to develop strong in-house technology capabilities.

Airtel is planning to enter the home automation or smart home segment with its IoT and machine-to-machine solutions in a move aimed at expanding its revenue base. Airtel is currently collaborating with gear vendors such as Ericsson, Nokia and Huawei to test technology and define certain initial use cases. In addition, it is working with South Korean firm SK Telecom to leverage the latter's expertise to build advanced telecom network and together work in developing 5G technology, network functions virtualisation (NFV), software-defined networking (SDN) and Internet of Things [88].

2.8 Some examples of 5G features implementation

This section is added in response to few comments in the preliminary review.

2.8.1 Remote and low latency feature

Ericsson demonstrated a 5G use case - remote control of sophisticated, heavy machinery. They remotely controlled Volvo excavator in Dallas, Texas from a connected simulator in FCC HQ. At the control end, the user had a VR headset with live immersive streaming video and operated the system via controls in the excavator simulator.

This demonstrated that with 5G, heavy machinery can be remotely controlled with real-time responsiveness where latency is a critical for safety. Advantage of this approach is that a worker with unique or specialized skills could manage multiple projects around the world in the same workday. Also, real-time remote control of heavy equipment allows for workers to operate in areas that are hostile in terms of weather or personal safety. Realizing the full potential of 5G requires cross-industry collaboration [89].

This is further explained in Sec 5.4.2 of Chapter 5 "Multi-access Edge Computing in 5G networks"

2.8.2 High-capacity and Ultra-reliability

Qualcomm has demonstrated that Coordinated Multi Point (CoMP) can extend 5G NR to high capacity & ultra-reliable communications. CoMP is an extension of MIMO and utilizes many distributed antennas to create multiple spatial dimensions for increased capacity and /or spatial diversity for reliability. RF blockage can cause sudden drop in signal strength. CoMP is effective against RF blockage and this is the key for reliability. 5G CoMP combines antennas form multiple small cells to create more spatial dimensions. Additional spatial dimensions allow simultaneous transmission to multiple users in the same geographical area while minimizing interference [90].

2.8.3 High capacity and high battery life

LG Electronics has announced that they will be releasing soon their new 5G smartphone with a longer battery life with 4000mAH batteries and has adopted vapour chamber technology to better disperse heat from the device. This is based on Qualcomm's latest Snapdragon X55 chipset which can power 5G enabled phone to support data heavy applications without latency [91].

Qualcomm has unveiled its new Snapdragon X55 5G Modem in MWC 2019, which enabled download data up to 7Gbps and upload data at 3Gbps on a 5G network apart from reducing power consumption. The full-dimension beam forming feature of this chip supports more users and boost network capacity, according to Qualcomm. Coupled with Qualcomm's QAT3555 adaptive antenna tuning technology, enables better indoor coverage and longer battery life [92].

2.9 Special Funding for Rural and Remote Connectivity

Different countries support rural connectivity by special provisions in law or through special funding mechanisms.

a) A large population in India live in remote rural villages. Private telecom operators do not provide connectivity to these areas, due to higher capital costs and lower revenues. Indian government has setup a fund called as "Universal Service Obligation Fund (USOF)". Every Telecom operator who does not provide rural connectivity has to pay a "Universal Access Levy" which is percentage of their revenue under various licenses, towards this fund. This fund is to provide access to ICT services at affordable prices to people in rural and remote areas. [93].

b) GSMA has launched a Innovation fund for rural connectivity with a objective of implementing digital inclusion by connecting remote rural places, through new innovative technology solutions. This fund is provided by UK government and managed by GSMA with the objective of developing solutions for providing rural connectivity in Uganda and Ghana, which can then be extended to similar environments [94].

c) UK's Wireless Infrastructure Group (WIG) has raised Pounds 220 million to enable rural connectivity through 5G ready wireless infrastructure [95].

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3.0 Socio-Economic Impact of 5G on Telecommunication Providers

3.1 Introduction

Telecommunication is very important and should always be available to all citizens. It serves as means for smart socio-economic well-being of the country. The largest impact of 5G technologies is on the Telecommunication ecosystem consisting of Telecom Service Providers or Telecom Operators. Telecommunication providers had hitherto focussed on traditional voice and data business. Technology advancements, consumer demands and regulations are driving new developments in this field, creating both opportunities and challenges. Telecommunication providers must anticipate the disruption and quickly adapt to changing situations to remain relevant. In this chapter, the author has explored the global trends in this domain, analysed the market demands consisting of both consumer and business demands. The author has explained the technology enabler to meet these demands and discussed the social and economic impact and finally discussed the impact on the business models and how this industry should innovate its business model to harness the opportunities presented and stay competitive.

3.2 Global Trends

Globally, Telecommunication providers are facing disruptions and are realizing the need to innovate their business models. There is a drastic change in the way the people and the businesses are consuming telecom services, bringing complexities into the current operations. Technology advancements are creating new opportunities and even impacting new market sectors. This is creating demand for new applications and services.

Telecom business is growing at a hectic pace across the world. Mobile data and video have been driving this growth. Some of the growth statistics are explained below [1].

- Mobile broadband services will be the main requirement. Mobile subscriptions had grown at around 4% year-on-year and reached 7.6 billion globally in 2017 Q1. 90% of the mobile subscriptions were for 3G and 4G/ LTE. Out of these LTE subscriptions itself contributed to 2.1 billion.
- Voice traffic growth has become very slow or stagnant as the increase in mobile subscriptions drives data consumption. Mobile data traffic grew 12% quarter-on-quarter and around 70% year on year.
- Independent Over-The-Top (OTT) vendors are entering into traditional messaging, voice and video business, which were forte of traditional telecom operators. OTT communication services are

increasingly bringing down the legacy voice and messaging revenues of telecom operators globally. OTT messaging has overtaken telecom operators' short messaging service (SMS) globally, as the most dominant form of messaging. International voice traffic is decreasing. The VoIP traffic contributes a significant fraction of international calls. The well-known OTT services are WhatsApp, Hike, Snapchat, Skype, YouTube, Viber, Facebook, E-Commerce sites like Amazon, online video games, Taxi aggregation services like Uber, etc. The revenue lost by Telecom Operators globally due to OTT services, is increasing year-on-year [2]. OTT services are reducing the traditional telecom service provider into just a platform provider.

- India and China represent the fastest growing telecom markets. The Indian Government has set a target of 600 million broadband users by 2020 capable of minimum of 2 mbps download speed and 100 mbps on demand [3].

- The strongest growth came from India and was followed by China. According to an analyst report the telecom operators in India carry most of the global internet traffic data in the world and its data usage grew 5 times in the last one year alone. India's network carries 2.1 exabytes of data per month, much greater than those in US, EU, China, Latin America and other parts of the world [4]. One of the reasons for the exponential growth in India, could be primarily due to one new provider, JIO, who gave attractive welcome offer with free voice and data. This had a huge take country-wide and has been instrumental in popularizing social media (like Whatsapp, Facebook), music, movie videos etc to the common man. This has created a fierce market competition and is leading to reduction of data cost across all operators. This trend is likely to continue with easy availability of cheap smartphones and penetration of high speed 4G networks.

- Video content will fuel the demand in future and video traffic is the prime traffic going forward and is forecasted to grow around 50% annually through 2022. A large Telecom Operator in India, Airtel, has attributed their business growth to video, which saw total data traffic on its mobile network grow by more than 550% to over 1 million Tera Bytes during quarter ended Dec 2017 [4].

- Smartphone will emerge as the preferred medium of entertainment over TV, Theatres, Radio, and newspapers. Mobile TV, powered by high speed connectivity, will dominate as it provides enhanced personal viewing experience anytime-anywhere access.

- Voice revenue will decline, and future growth will be in Data and Video.

3.3 Market Demand/ Drivers

Following are the market demand drivers:

3.3.1 Consumer Drivers

Availability of cheaper smartphones and a competitive telecom market has driven consumer awareness of the opportunities possible through smartphones. Consumer, globally, are increasingly using smartphones for communication, entertainment, and social networking purposes. This has fuelled the demand for exponential consumption of data and video content.

Consumers want to be in touch with family, relatives, friends, social circles and business contacts at all times and at any place in the world. Social media applications like WhatsApp, Facebook, Hype etc have become almost mandatory in the life of most of the people in developed and developing countries. Consumers want to be able to use smartphones to perform most of the online work, like banking, stock trading, airlines/railway/ bus ticketing, hotel booking, travel planning etc. Smartphones have become very necessary for navigation through traffic and search destinations and provide the optimal routes. Consumers want to use smartphones even for their basic health check-up. They demand games and videos even when they are on the move. They also want to use phones as a medium for delivering education due to its convenience.

Consumer preference is changing towards smartphones as the preferred medium of entertainment over TV, Theatres, Radio and newspapers as it provides enhanced personal viewing experience anytime-anywhere access. Ultimately, the demand is for **always on** mobile services

3.3.2 Business Drivers

Businesses want to have new services or enhance their existing services, through the mobile device. Businesses demand mobility as an enabler of increased business productivity, enabling the ability of employees to work from any location on any device. They always want to be connected with employees, customers and associates. They would want their employees, who are always on the move like Sales and Field support, to be able to do all the official tasks through their mobile devices. Almost all businesses nowadays want their consumers to connect with them and do business on through their mobile device. Even services like Healthcare would want smartphone to be used to test some basic health parameters and aid in remotely monitoring the patient.

The demand is for the ability to connect billions of devices and manage them. Communication technology should support this. Real-time applications need very low latency and high-speed network. Certain business wants to own a slice of the network on their own, so that they can service their clients and provide SLAs to ensure longevity and guarantee of service. There is also a demand from small operators to operate as private virtual network operators, by buying bulk bandwidth from telecom operators and creating their own operational support system/ business support system (OSS/ BSS) systems to manage their exclusive customers.

Also, certain Utilities which are characterized by mission-critical applications, would like to have a total control on their communication network by owning and managing a certain portion of the network. Faster networks are demanded to connect vehicles on the move and to support autonomous cars.

3.4 Technology Enablers

5G features has the ability to create a revolution in connected society, by transforming the role played by wireless technology. 5G will evolve from the existing 4G/ LTE but bring a drastic change with the ability of connecting billions of devices and managing them in real-time.

5G characteristics that will enable rich communications services and meet the demands as detailed above, include:

- Data rates of 10Gb/s supports both uplink and download of video rich services over wireless networks, which are required for ultra-high definition video and virtual reality applications.
- Ultra-low latency of less than 1 mSec, enables enhanced user experiences potentially including the delivery of 3D images and holograms and other applications like vehicle-to-vehicle connections, remote surgery, on-like gaming, augmented reality etc.
- 10 to 100 times faster and higher capacity than current 4G LTE networks allows video content to load faster on mobile devices and supports creation of new innovative applications.
- Operation in both licensed and unlicensed frequency bands. Benefits of licensed bands would be less interference from other wireless systems leading to better resilience and useful in mission critical applications. Some use cases not requiring stringent needs, may be ok with unlicensed band which does not require license fee.
- Massive machine type communication (MTC) including Device-to-Device (D2D), interoperability with satellite-based systems as a means of extension of coverage. This feature of extending coverage especially indoor and in rural areas would be very useful for various applications.
- Massive MIMO- where large number of antennas are used to increase the reliability of the link and to extend the coverage.
- 5G's software-based network architecture enables dynamic provisioning of the right control layer for different applications. This support of network slicing allows creation of Virtual Network

Operators who can buy bandwidth from the telecom operator and offer their own services to their customers.

- Always on connectivity supports services in high mobility environments such as cars, planes and high-speed trains. Reliability is boosted by combing several wireless technologies
- 5G offers enhanced security.
- New innovative business models are enabled by 5G across various industry and consumer segments.

3.5 Socio-Economic Impact

3.5.1 Social Impact

Consumers of Telecom Operators would be benefitted by the new opportunities provided to them, enabled by the superior features of 5G. Apart from the typical individual consumers, Telecom Operators would partner with large enterprises and utilities across various verticals, who also would become customers or partners. Connectivity would be made available to customers anytime and anywhere, resulting in death of distance.

Customers will enjoy a far superior mobile internet experience and get new innovative applications and services in domains like Healthcare, Intelligent Transport Systems, Energy systems, Educations, Smart Cities, Safety & Surveillance, Retail, Hospitality, Home automation etc. In fact, it will touch them in every aspect of living.

Social benefits of connected health include transition from present specialist drive hospital-based system to a patient cantered care model with remote delivery of healthcare services. This is very important for elderly and those people who cannot easily visit hospitals.

Social benefit of intelligent transport systems include advanced driver assisted systems with predictive alerts, rear-collision warning system, lane departure warning, blind spot detection, collision avoidance, pedestrian detection, voice-activated alerts via mobile phone, warning of an upcoming traffic incident or public transport service disruptions, real-time web and app-based comparisons of multiple routes or transportation modes and how long they would take, recommended departure times to avoid being stuck in traffic and/or transport delays, GPS navigation visible on car windshield etc.

Social benefits of smart energy include enablement of consumers to become prosumers, i.e they can produce energy as well as consume it, have better choice of quality of service, have flexibility of purchasing power from different sources and reduced outages and downtimes.

Social benefits of smart education include enablement of experiential learning by real-world environment simulation, remote access to multimedia learning, interactive learning through smartphone/tablets and virtual classrooms.

Social benefits of smart homes include remote monitoring of homes and control of devices/systems, getting video content based on family's preference across multiple devices, and immersive experience to home viewing through AR and VR.

Social benefits of smart surveillance include safety & Security of all people, city wide video surveillance, home safety, women/citizen safety in public transport vehicles, citizen response management and reduction of crime and terrorism.

3.5.2 Economic Impact

Telecom Operators will be able to deliver faster connectivity, communication, and content anywhere, anytime without much perceived delay. They would be able to deliver services on multiple devices and interfaces. It will be possible for sessions to be transferable from one device to another transparently.

Telecom Operators can look beyond their traditional business, into new areas and opportunities enabled by 5G. They can conceptualize new use cases in sectors like manufacturing, energy, utilities, automotive, education, content service providers Smart homes, Security & Surveillance, and healthcare, which were not their area of focus earlier. New areas of partnerships are emerging between Telecom Operators and non-traditional entities. One example is a Telecom Operator, British Telecom, which has entered Energy sector with a partnership with two other companies under a new brand name SmartReach [5]. New use cases will emerge, as the implementation of the technology progresses.

The initial implementation is expected to be around enhanced mobile broadband (eMBB) and Fixed Wireless Access (FWA). This enables high-demand applications such as augmented and virtual reality (AR/VR) and ultra-high-definition (UHD) video (4K/8K). Beyond enhanced mobile broadband, networks will be able to handle use cases with different demands on mobility, data rates, latency, reliability, and device density.

Telecom Operators cannot operate in isolation. They will have to partner with the customer verticals and jointly bring new revenue generating services. The telecom ecosystem will have to bring new devices capable of supporting 5G services and use cases. Over time, 5G will enable a wide range of use cases for massive Internet of Things (IoT) and critical communication [6]. The IoT sensor network would involve billions of devices which may not necessarily ne SIM based. Telecom Operators will have to develop methods to authenticate such devices. This would involve large operational change [7].

The business cases enabled by 5G, may necessitate to support vertical industries and this would involve a new set of partnerships to be established with different players in the ecosystem. Further, it may involve integrating partner's services into their own network, exposing their own specific network capabilities and infrastructure sharing. The network changes and the upgrades that the Operator must do, involves a huge capital investments and technical resources. Work on 5G Standardization is still underway. Since technology is not proven, it would involve extensive trials before finalizing the networks.

Telecom Operators will be able to provide network slicing using network function virtualization (NFV) and software-defined networking (SDN) features within their existing networks. Resources can be assembled dynamically into specific network slices that supports different applications. Each of these slices can be optimized for the exact needs of specific applications. So, we can have one network slice which is customized for, say, connected vehicles and autonomous cars, by provisioning very low latency and high bandwidth. Another slice can be customized for smart energy applications and so on.
By this customization, diverse use cases can be supported, and resources are used more efficiently, and businesses will be able to provide Service Level Agreements (SLAs) to their customers.
This will enable support to new and innovative business cases across various sectors.

Telecom providers will be able to implement highly reliable, scalable, resilient and secure networks. They will be able to provide support seamlessly across technologies. They will be able to provide personalised experience by providing services enhanced by contextual and personalised attributes. They will be able to support faster downloads and real-time multimedia with immersive experience. They will be able to provide a flexible and programmable network infrastructure built on common platforms that adapt to any cloud-based applications and be able to accommodate varying traffic demand. They could offer advanced analytics to control and manage the entire network, with end-to-end security built in.

Carriers and service providers must prepare their networks for the scale and flexibility that is required to provide highly cost-effective solutions that support exponential increases in network demand, a wide variety of devices and applications, higher data rates, lower latency, and greater power efficiencies – all while maintaining a low cost per gigabit service model. The entire supply chain will be affected by this revolutionary development.

There is a massive increase in data traffic and revenue is either declining or not keeping up with growth in demand. This results in Lower revenue per user in saturated markets. The features of 5G will enable Telecom operators to develop new applications and services, enabling them to enter new business domains. They will be able to innovate their business models to stay competitive and profitable.

3.6 Impact of 5G on Telecom Operator Business Model Innovation

Earlier, telecom operators had been a pure voice player and progressed to become a "triple play' player by being able to deliver data and video along the voice. Now, with 5G technologies, Telecom Operators will be able to innovate their business model to enter new domains [8].

3.6.1 Traditional Telecom Business Models

This section discusses the evolution of the business models adopted by Telecom Operators over a period. It traces the developments from a pure voice player to becoming a 'Triple play' player i.e delivering the triple service of voice, video and data and later their market expansion. Further, it discusses the outsourcing of certain functions like network to Original Equipment Manufacturers (OEM) and IT to System Integrators. Then, it looks at the advent of leasing bandwidth to Virtual Network Operator (VNO).

3.6.1.1 "Broadband Business" Model

Till about 2 decades back, dial-up voice used to be the primary telecom business and copper wire used to be medium. During the millennium transition, telecom business was disrupted by Cable operators who started offering high speed broadband data service on Hybrid Fibre Co-axial (HFC) network in addition their cable video services. The author has named this as **"Broadband Business Model".** This became very popular and had a rapid growth. This forced Telecom operators to install fibre network and start promoting bundled offerings by integrating voice, data and video services, which came to be known as 'triple play' services being delivered through a single cable coming into the customer premises. The pioneer in this initiative was C&W Optus in Australia. Those operators who had legacy copper infrastructure only, introduced a technology called Digital Subscriber Line (DSL) to offer triple play services.

The "Broadband Business Model" defined by the author can be correlated the 'Connectivity business model' defined under the 4C business model typology by Ahokangas P et al in their scenario-based business model theory [9].

Many of the global telecom incumbents having copper infrastructure only, were users of DSL technology. Telecom operators upgraded their own infrastructure to deliver these services or partnered with cable operators or content providers. The onset of 3G saw a growth in Mobile broadband, the business model of which was similar to the HFC/ DSL model. The services offered over the top of the broadband network, made it very popular. This model was initially a **'flat rate model'** i,e fixed periodic rates. However, as the consumption increased, different data plans started to emerge and has finally moved a fixed price for unlimited data by some operators. The user benefitted from a simple cost structure while the service provider benefited from a constant revenue stream.

Gassman et al. defines such a pattern in their 'business model navigator' as "Flat Rate" business model pattern, where is a single fee for a product or services is charged, regardless of actual usage or time restrictions on it [10].

3.6.1.2 "Market Acquisition" Model

Telecom Operators started to expand into new markets to address new customer segments, owing to either saturation or intense competition in the home markets or as a strategy for growth. Many operators created new markets through joint ventures or acquisitions to enter new markets. Example – India's large Telco entered African market through acquisition of the African operation of Zain [11]. The author has termed this as "**Market Acquisition model".** This model should consider expanding to new markets by analysing what other markets exists for its products/ services. Factor to consider include the potential markets offering the greatest sales and growth opportunities, ability to identify the right kind of local player for partnership/ acquisition, favourable regulatory and taxation policies, easiest to reach etc.

Osterwalder et al defines this under their business model ontology as a 'Partnership Network' business model element, which are used for creating joint ventures or strategic alliances to penetrate new geographic markets [12].

3.6.1.3 "Outsourced Managed Services" Model

Technology advancements led to frequent equipment changes which needed upgrades and software updates. It would be difficult for Telecom Operators to keep track and manage the technology. This led to many of them outsourcing the technology portion completely to the Telecom OEMs themselves and manage through strict outcome-based SLAs. The telecom operation management like Operation Support Systems / Business Support Systems, were outsourced to IT vendors. The author has termed this as "**Outsourced Managed Services model**". The Operators now could concentrate on market acquisitions and customer experience management only, which was their true strength.

Osterwalder defines such an arrangement as Partnership Network Element [12] wherein there is a voluntary agreement between the telecom operator and the IT vendors to carry out certain portion of the value chain under a service level agreement.

3.6.1.4 Virtual Network Operator (VNO) model

Telecom Operators also started selling capacity in wholesale to smaller Operators, who would deliver services to their own set of customers. They create their own service delivery platform and handle customer service, billing and value-added services to their own subscribers. These Operators did not own spectrum or telecom infrastructure and were virtual. Author calls this as "**Virtual Network Operator (VNO) model**". Here, the VNO buys capacity from the Telecom Operator and resells it with added value to its dedicated set of customers. The Telecom Operator is benefitted by being able to sell in wholesale without the trouble of acquiring and managing customers. They could expand very quickly by having multiple VNOs in different geographies.

This model could be correlated to 'Utopia' scenario defined by Ahokangas P et al, in their scenario-based business model theory, wherein the VNO create and capture value through connectivity, content and context, but are reliant on the Telecom Operator's infrastructure [9].

Gassman et al. defines such a pattern in their 'business model navigator' as "affiliation" business model pattern, where the company is supporting others (like VNOs) by providing spectrum capacity and benefitting from this capacity sale. VNO benefits by selling their own products or services to their own customers. Here, the company to sell [10].

Osterwalder et al defines this under their business model ontology as a 'shared infrastructure" business model, where the infrastructure in terms of capacity is shared for a cost by the telecom operator to various players [12].

3.6.2 Challenges to the traditional Telecom Operators business models

Customer behavior and expectations are fast changing, giving rise to exponential consumption of data and video content. The Over-The-Top (OTT) services are affecting the Telecom Operator's business, as the OTT players can offer these services without owning, leasing or operating a network. OTT services are applications like social networks, video and messaging services etc. which are accessible over the internet and ride on top of Telecom Operator's networks. Customers can access these directly on their smartphones from anyplace. Telecom Operators business models are impacted by this as their revenues are solely from the increase in data usage and not from the applications and services.

OTT players use the telecom networks established by telecom operators, as a platform for development of new services, which creates demand for faster networks which needs to be implemented by the telecom operators along with upgrade of OSS/ BSS systems. This is an additional financial investment requirement for the Operators.

The Telecom Operator whose network is utilized for delivering the OTT services, has no control, no rights for the content on these services. Thus, it is evident that the Business Models of Telecom Operators are impacted by OTT players. The traditional income model of the operators, based on subscriptions and metered services, mainly voice and messaging, is failing.

The main challenge faced by Telecom Operators by the OTT players are that they are offering voice and messaging services, traditionally provided only by Telecom operators. OTT messaging has overtaken SMS globally as the most dominant form of messaging. International voice traffic is decreasing. and the VoIP traffic is increasing. VoIP traffic contributes a significant fraction of international calls. The revenue lost by Telecom Operators globally due to OTT services, is increasing year-on-year. Thus, OTT players are competing with Telecom Operators without any investments in building networks. However, this is leading to increased data revenues for the Operators, but profitability is declining. With the increasing proliferation of Smart phones and OTT based voice and video calling services such as WhatsApp and Skype, regulated legacy voice services could lose significant market share.

The traditional voice and fixed-line business is declining leading to lower profitability. Subsequently, their old business models are coming under increasing pressure and appear to be crumbling. Telecom Operators must reform their conventional ways of business and enter new domains enabled by the features of 5G. The dawn of the digital consumer, reduction of traditional voice revenues and emerging new opportunities in various domains, require telecom operators to innovate their business models to stay competitive and profitable.

3.6.3 5G Business Model Innovation Potential

The features of 5G described earlier, has to potential to create new business models. 5G will expand the addressable market. In additions to the services like location-finding services, multicast services, etc, 5G will enable new services like player-perspective gaming, connected vehicles, self-driving cars, remote healthcare management, Industrial automation, augmented and virtual reality etc. This provides a huge potential for creating new target markets with respect to the value proposition and challenges in deciding on the offerings, markets and the partnership they have to forge.

Another key enabler for business model innovation is the network slicing feature of 5G, which can create unique slices of the network through network function virtualization and these unique slices could be customized for the requirements of any industry. These slices can be programmed wherein the network can dynamically adjust to any given requirement. This has the potential to create new business models [13]. 5G can enable network as a service wherein different profiles can be used for different applications.

3.6.4 Telecom Operator's Business Models in a 5G world

The author has discussed the challenges faced by Telecom Operators to their traditional business models and the opportunities provided by 5G to innovate the business models to remain competitive.
Providing connectivity is the basic function of a Telecom Operator. Average revenue per user (ARPU) growth, subscriber growth and connectivity to IoT are the key considerations here. 5G features will enable enhanced connectivity which provides opportunities for new business model approaches in creating partnerships with content & application providers, OTT players and transformation as a digital service provider. Various possibilities are explored, analysed and compared to bring out a suitable framework for telecom operators.

3.6.4.1 'Partnership" -- Business Model

The telecom infrastructure is the key asset of the Operator, which is used to deliver its own services. The Operator could lease a part of their wholesale business to a third party.

The feature of 5G high level requirement of allowing creation of different levels of relationship between operators and application/service providers, facilitates this business model. The key requirement of this model is that the 3rd party Service providers should be able to configure and manage the service, while Operators will have freedom to manage and evolve the network. 5G provides an abstraction layer as an interface, where all types of in-networking functionality can be exposed to the application layer functions and/or service providers based on a service level agreement. Application/Service provider will then be able to use sub-set of the network capabilities in a flexible, configurable and programmable manner, and to use network resources depending on their service preference and thus creating a separation from the Operator.

The following model approaches could be followed:

3.6.4.1.1 "Integrated Services" Business Model

Here the Operator could provide integrated service offering based on their own capabilities enriched by a Partners content and specific applications. The real-time asset provisioning feature makes this possible. Integrated streaming solutions can be an example here but even services such as payments are possible.

Osterwalder defines such an arrangement as Partnership Network Element [12] wherein there is a voluntary agreement between the telecom operator and the IT vendors to carry out certain portion of the value chain under a service level agreement.

3.6.4.1.2 "OTT/ 3rd Parties Partnership" Business Model

Telecom Operator could partner with 3rd party provider or with OTT provider, wherein the partners could directly make offers to the end customers enriched by the operator network or other value creation capabilities. Examples are Smart wearables with remote health monitoring. The customers buy clothes from a manufacturer and take benefit of the health monitoring feature offered by the 3rd party, enriched by the operator's set of network and value creation capabilities. Telecom Operators could work closely with content owners that serves mutual interests with the objective of consumer satisfaction. It is expensive for Telecom Operator to build high-bandwidth data networks to enable data intensive content services. They should create models in co-ordination with content players, wherein QoS provisioning is made to ensure network asset monetization. In this model, the Telecom Operator should work with content providers to create dramatically different pricing models that move away from charges for data consumption.

Gassman et al. defines such a pattern in their 'business model navigator' as "franchising" business model pattern, where the Operator allows the partner to use his network and provide services directly to his (partner's) customers[10].

3.6.4.1.3 "Partner with MVNO" Business Model

Mobile Virtual Network Operators (MVNO) are extensions of the Telecom Operators who connect with their networks and deliver services to their own set of subscribers. MVNO does not own spectrum of access infrastructure but provide telecom services by purchasing capacity from the Telecom Operator. MVNOs play an important role in the telecom market by buying wholesale bulk minutes from the Telecom Operators and selling them to consumers at a discounted price. They handle end-to-end management of service creation, marketing, customer acquisition, SIM card creation & distribution and subscriber provisioning. They create their own service delivery platform and handle customer service, billing and value-added services to their own subscribers. They will be responsible for QoS obligations for their customers. They will have to maintain their own usage records, systems and tools to service all legal requests of the regulators and would be responsible for maintaining data privacy & security.

The advantages for the Telecom Operators in this model are that they can sell a part of their wholesale business, without having to worry about customer acquisition, niche service offerings and customer management. They can have multiple MVNOs. In this way, they were able to expand into niche markets very quickly, able to increase their market share rapidly by effectively utilizing the unused/ Under used capacity. Here, the telecom operator can also provide VNO end-to-end delivery of regulated roaming calls, SMS and data, increasing their revenue.

MVNO business is expanding. Informa Telecoms & Media [14] forecasts that there are an additional 150 million MVNOs customers available where the growth prospects are provided by the ethnic market, youth-oriented, fixed line operators, retailers and M2M/ IoT segments. Capgemini projects that the youth, lifestyle, enterprise and data-driven emerge as the most attractive opportunities for MVNO entry in India [15]. Industry verticals like Banks, large retail enterprises, large content & media players, DTH operators, broadband players, OTT players, FMCG companies, private energy suppliers, transport industries etc have the opportunity to have their own independent telecom services as MVNO players[16].

This model could be correlated to 'Utopia' scenario defined by Ahokangas P et al, in their scenario-based business model theory, wherein the VNO create and capture value through connectivity, content and context, but are reliant on the Telecom Operator's infrastructure [9].

Gassman et al. defines such a pattern in their 'business model navigator' as "affiliation" business model pattern, where the company is supporting others (like VNOs) by providing spectrum capacity and benefitting from this capacity sale. VNO benefits by selling their own products or services to their own customers. Here, the company to sell [10].

Osterwalder et al defines this under their business model ontology as a 'shared infrastructure" business model, where the infrastructure in terms of capacity is shared for a cost by the telecom operator to various players [12.]

3.6.4.2 "Digital Services provider" Business Model'

The core voice/data connectivity business of the Telecom Operator is getting saturated with revenues not growing in line with data growth. The increasing Capex and stagnant revenues make the connectivity model unprofitable in the long run. To take advantage of the future digital economy, Telecom Operator could extend beyond providing the core connectivity services and transition to digital services. This could involve services like TV/ video content, Financial services, Education services, Smart homes etc. The advantages of this model are the direct revenues generated from the new digital services. However, these services could be low margin services when compared to the Telecom Operator's core connectivity business and the gestation period could be longer, impacting quick return on investments. However, the advantage is that this will reposition the Telecom Operator as a 'Digital Service Provider" who is in synch with the changing consumer behaviour resulting in customer acceptance and loyalty.

All the features made available by 5G could enable the Telecom Operator's '**Digital Services Providers'** business model. It opens a world of new opportunities to be addressed in new vertical markets. 5G's modular network architecture provides programmability and flexibility to provision only necessary functions in the network. Features like 5G's ultra-reliable low latency communications and massive machine type communications, which involve sensor network and IoT, will enable Operators to develop cutting edge applications to address multiple market segments. This opens new avenues for Operators to develop digital applications to address Industries 4.0, Smart Cities, Smart homes, Healthcare, Utilities, Retail, Entertainment etc.

In the full 5G world, however, we will see additions like player-perspective gaming, augmented and virtual reality. This provides a huge potential for creating new targets with respect to the value proposition and challenges in deciding on the offerings, markets and the partnership they have to forge. This creates a huge potential for the Telecom Operator to explore, build and offer their own suite of digital services. Network slicing features provided by 5G, enable Operators to create 'slices' of their networks through virtualization technology which could be tailored to the needs of any vertical industry like automotive, healthcare, logistics, retail or utilities. This would enable Telecom Operators to be a full player in digital services across all vertical segments.

Telecom Operators could offer Video services or Messaging app services, as part of their digital services offerings.

3.6.4.2.1 "Operator-led Messaging App Service" Business Model

Messaging apps have become extremely popular and some of the global names are Whatsapp, Line, Nimbuzz and Hike. Telecom Operators could also get into developing their messaging apps as an upsell for their customers. There is scope for multiple players in the messaging market as every user has 2-3 messaging apps on average. The adoption could be slower due to the high competition and stickiness nature of the apps. Users will use the messaging app that has the widest reach with most of their friends and social circle.

There are no subscription charges for the messaging app and it will not increase data revenues given limited data usage on these apps. There is limited differentiation potential for standalone messaging service given no subscription charges and hence no bundling opportunity. Monetization could be only from advertisements based on user profiles. This could be viable only if the user base becomes large. A new player in this space would already be 4-5 years behind in terms of market entry. So, a new entrant will not be able to ramp up quickly and become one of the top global players, to be used by a large user base. This is not a profitable model in the shorter run.

3.6.4.2.2 "Operator-led Video Service" Business Model

Countries like China and India are high consumers of video content, where it is a high engagement service. Video led services offers the best option for the Telecom Operator to enter digital business. An Operator led video service will be beneficial from sizable indirect revenues from own customers, in addition to direct revenues (subscription revenue).

The indirect revenues are accrued from the increased mobile broadband user base and the increased ARPU. Also, Operator can expect a reduction in churn due to the stickiness of the digital services.

The direct revenues will accrue based on the subscription revenues, app purchases and advertisements. From the cost side, Content and Subscriber acquisition cost are two biggest cost components with additional indirect (network) costs associated with indirect revenues.

Acquiring exclusive rights for some popular events will be beneficial for Operators, especially sports events which are popular in those countries.

Operators could build their Video services in the following ways:

3.6.4.2.2.1 "Build for Own Customers" Operator-led Video Service Model

Here, the Operator can build their key applications only for their subscribed customers. This is a walled garden approach. Here the advantage is that customers are already existing and owned by the Operator and no additional customer acquisition costs are involved. They can build differentiated services to its own customers. However, revenues would be limited as the service is limited to the subscribed customers only.

3.6.4.2.2.2 "Build for Open Access" Operator-led Video Service Model

Here, the Operators can build video-based applications and could give open access to anyone from any other carriers/ operators. The advantage is that Open access market is larger, where Operators offer their services to anybody i.e carrier agnostic customers. This has a high revenue potential which includes direct revenues from their own and other customers and indirect revenues from other customers. The payback period could be higher as additional investments are needed for customer acquisition. However, net profits would be larger as more open users could be expected outside the subscribed users.

Gassman et al. defines such a pattern in their 'Open Business Model" pattern, where the Telecom Operator partners with application developers to develop custom applications for them [10].

Ahokangas P et al, [9] in their scenario-based business model theory have explained about a similar scenario called "MNO's Law and Order' where the Operators' platform and interfaces control the horizontal business and services. This scenario is customer-oriented since the more local services are expected.

3.6.4.2.2.3 "Partnership" Operator-led Video Service Model

Here, the Telecom Operator does not build their key applications, but they get their partner to build the applications. Here, time to market is very less I.e. they can partner with existing OTT application provider or Content provider and investment is much lower as direct or indirect costs are not involved. As costs are not involved, payback period is not applicable. However, the disadvantage is that because of revenue sharing, the revenue will be very less when compared to the revenue obtained by OTT provider. Gassman et al. defines such a pattern in their 'Open Business Model" pattern, where the Telecom Operator partners with application developers to develop custom applications for them [10].

3.6.4.3 3 "Micro Operator" Business Model".

Most of the countries have few incumbent Telecom Operators who have purchased spectrum licenses at very high costs through auctions, which are generally for very long durations covering large areas. These benefit very few large Telecom Operators. Even though they have certain benefits in maintaining lower interference and QoS, it has resulted in market barriers for new niche players.

Digital transformation of various industry verticals will create demand for local services and indoor networks with spectrum sharing. Networks scalability would be needed as per demands. As vertical industries grow, there would be need for specialized connectivity solutions for these vertical industries which may be better addressed by niche players in such verticals. Network slicing and providing "networks as a service "allows multiple stakeholders to have their own network. 5G deployment may require indoor coverage and location-specific services on-demand, which is a challenge for traditional telecom operators. This could create local Micro-Operators who could share spectrum with established Telecom Operators and provide their own services independently.

Spectrum sharing solutions are important in making new spectrum available to enable different 5G networks to coexist, while the incumbent's spectrum user's right is protected [17]. Since, many verticals would be impacted by 5G, it would be easy for the Micro-Operators to speed up 5G deployment. This would also benefit Telecom Operator's consumers in addition to micro operator's own customers. 5G is supportive of such a model due to its network slicing and NFV features. Micro operator would plan, build, operate and maintain the local small cell infrastructure and provision customized solutions in the specific region. They could serve machine type requirements such as inside an industry or inside a large campus, which are not served by the traditional Telecom Operator.

New local licensing models will be needed to complement existing models to allow different stakeholders to establish local 5G small cell radio access networks with guaranteed quality. Spectrum assignment and sharing is important in a 5G context to determine who can use 5G bands. Specific spectrum access regulations need to be made available for local 5G networks who are serving vertical industries. Regulation should encourage competition to enable Micro-operators to serve specific local verticals independently.

Small 5G network deployments should be able to connect to other Telecom Operators for end-to-end connectivity and regulation should ensure that there are pricing controls. Data analytics is the key for enabling vertical use cases and there should be regulations defined for data collections and analysis. Licensing models should enable easy establishment of small 5G networks.

Typically, a Telco deploys network in its own licensed spectrum. Further, they could engage Micro Operators, who would develop a private network with leased spectrum from Telco. New spectrum will have to be given for 5G; regulators should also allocate independent spectrum licenses in the new 5G bands to many 5G micro operators to create networks for different industry verticals. This will help in accelerating deployment of 5G by smaller independent local 5G micro operators, as they could work independent of large Telecom Operators.

Regulations should encourage innovation by making spectrum available at reasonable costs to local micro operators. This is very important to accelerate deployment of 5G across different verticals [18].

5G Micro Operators would offer various services in their local areas for specialized use cases in different verticals. This would need micro licensing, where the regulators must develop suitable procedures for awarding micro licenses to the local micro operators including new operators. Co-ordination amongst licensees are required. This has the benefit of allowing new innovative smaller players who could address specific verticals in local markets efficiently. Interference protection can be predefined ensuring defined QoS.

Micro licensing would be better than allowing operation in license exempt bands, as there is better control of interference and assured predefined quality. Countries such as Finland, Italy, Ireland, Japan, Germany and USA, have already implemented this on the 3.5Ghz band [18].
US regulator FCC allows sharing model in the 3.55 to 3.70 Ghz band that enables market entry for different players with local access rights and in Europe Licensed Shared Access concept was standardized and trialled in the 2.3 to 2.4 Ghz band to enable local mobile network deployments and is extended to 3.4 – 4.2 Ghz [17]

<u>Business Opportunities for Micro Operators</u>
Wirtz et all [6] have defined 4C business model logic for internet businesses, based on connectivity, context, content and commerce [19].
Micro Operator's service opportunities could include all layers of the 4C business model logic i.e connectivity, context, content and commerce [18]
The business opportunities for Micro operators are:

- They can operate local small cell networks in selected areas to serve Telecom Operators' consumers.
- They can offer a secure closed local network addressing verticals with pre-defined access to the outside world. Examples are factories and hospitals.
- They can offer specially customized services such as premium content services, say for education and smart homes.
- They could also broker data generated and analysed, to different industries like intelligent traffic systems, smart cities etc
- They could also be responsible for real-time data transactions and management of certain applications. This could be additional source of revenue. This could be ideal for IoT based applications, wherein huge amount of data is generated and has to be analysed in real-time.
- They could apply big data analytics and machine learning to derive deep insights useful for business.

Ahokangas P et al, [9] in their scenario-based business model theory have explained about the emergence of Micro Operators. In a scenario where regulation gets complemented with local short-term licensing, Micro Operators would emerge for providing content-specific services which will have its specific mode of monetization. Competition will increase in the market with Micro Operators competing against themselves and with the traditional Telecom Operator. New use cases can be expected in vertical markets. Suppose in a scenario where regulation has become very friendly leading to sharing of resources, business will become service centric. Locally produced content can be provisioned and distributed to different segments. Local services providers can buy and sell services too, leading to Prosumerism. This scenario is called as 'utopia' and is most preferred as end consumers are benefitted with competitive products.

3.6.5 Suggested Business Model Framework for Telecom Operators

As a high engagement service, it makes business sense for an Operator to build and control this service itself, as detailed in section '***3.6.4.2.2.2'*** rather than partnering with a 3rd party provider, as they can exercise greater control over user experience and product offering e.g. optimizing the product for network quality as well as being able to bundle the product with core services. These are indirect benefits. Hence, owning content and thus managing the complexity in-house has its advantage in terms of ensuring business continuity, as well as provide potential scale benefits. However, this needs large investments, a change in organisation culture and longer time to market.

Telecom Operators could get revenues from:

- Direct revenue from both 'own' and 'other Operator's' subscribers
    - Subscription revenue – revenue from premium services which requires subscription
    - Advertisement revenue—Digital advertising revenue, typically structured on a per click / impression basis
    - In app purchases (Physical and virtual) – revenue from sales of physical (Ecommerce) or Virtual (like games etc)
- Indirect revenue from own subscribers only
    - Increased Data users – Upsell non-data subscribers by bundling paid subscription along with data pack
    - Improved Customer retention – Reduce Customer Churn by differentiating through a digital services portfolio
    - Increased Data ARPU – Migrating customers to higher data bundles due to increased data consumption'
    - Customer analytics – Monetization through selling customer analytics leveraging on customer data.

Unlike a pure OTT provider, Operator offering digital services gets Indirect revenue from its own subscriber base. This is an added advantage for the operator and a motivator to start its own digital services. Therefore, Operator gets both direct and indirect revenue when offering its own digital services.

On the Cost side, there are two cost elements.

- Direct Cost – Marketing, customer acquisition, content development / distribution, all other operational costs
- Indirect Cost – providing the voice and data services to indirect revenues. Indirect cost is a cost element required to earn indirect revenues from own subscribers of the operator, like increased

data users, enhanced customer retention, increased data ARPU and monetization through customer analytics etc.

The cash flow would be (direct + indirect) revenue – (direct +indirect) costs.

Return on investments could be faster, if the Operator does not invest own Capex but launches Digital services on SaaS/ Opex only platforms.

Telecom Operators needs to change the Business Model incrementally. Over the years, they have become large complex organisations with multiple layers. This can create barriers to innovation. They may take a very long time to bring out a product, as they have to adhere to stringent process and work with multiple cross functional teams. In contrasts, OTT player is typically a start-up and have can develop products iteratively and very quickly. So, Telecom Operators should change the culture of the organisation when they attempt such a development and bring in external expertise.

Summarizing, It will be beneficial for the Operator to ***build its own digital services and applications and provide Open access*** to all including both paying and non-paying subscribers of the service, as it can get much larger revenue due to large target market which is carrier agnostic. Overall, this strategy helps in building a digital brand with targeted promotions and product bundling. This would transition the Operator from a pure voice player to a Digital player.

Ahokangas P et al, [9] in their scenario-based business model theory, have explained about a similar scenario called "MNO's Law and Order' where the Operators' platform and interfaces control the horizontal business and services. This scenario is customer-oriented since the more local services are expected.

3.7 Summary

- Telecom Operators must prepare their networks for the scale and flexibility that is required to provide highly cost-effective solutions that support exponential increases in network demand, a wide variety of devices and applications, higher data rates, lower latency, and greater power efficiencies – all while maintaining a low cost per gigabit service model.

- Business model innovation is perhaps the single biggest innovation 5G will bring to the market and Technological advances towards 5G along with greater industry consolidation, will transform network economics**.** Business models should focus on data and video market segments and should include greater industry collaboration with Network sharing.

- Telecom Operators should move from providers of low growth connectivity model to aggregators and innovators of digital offerings. Telecom Operators will need to continue to stretch the boundaries of what current revenue models allow. While they have traditionally followed Business-to-business and Business-to-consumer models, increasingly, innovative Business-to-business-to-consumer models are more likely to be the norm in the future.

- The ability of operators to develop any of earlier explained business models will depend entirely on their individual circumstances and market conditions. Important is that they need to act now to consider which options will suit their business best in the "5G world"
- "Build own video services for open access" model is beneficial for Telecom Operators in the longer run, which also helps in building a digital brand with targeted promotions and product bundling. This would transition the Operator from a pure voice player to a Digital player.

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4.0 Socio-Economic Impact of 5G on Healthcare Services

Healthcare services can be vastly improved by use of telecommunication network / services by giving accessibility of health services to elderly and those in remote areas. It can enable patients to interact with healthcare providers remotely from their personal sensor devices which transmits their vital signs. 5G technologies will further augment this trend and enable new possibilities in the healthcare domain.

4.1 Global Trends

- United Nations estimated that in 1950, people aged 60+ were 8% of world population, which increased to 12% by 2013. It predicts that by 2050, the 60+ aged people will be around 21% of the total world's population, with 80+ being around 4.1%. So, the global trend is that life expectancy is increasing, and the aged population will increase exponentially globally [1].

- Population ageing has major implications on economic growth, savings, investment, consumption, labour market, pensions, taxation etc. It will also affect healthcare in a major way. The increase is the result of demographic transition from high to low level of mortality. Most older persons are women as female life expectancy is higher than that for men [1].

- The health of older persons typically deteriorates with increasing age, inducing greater demand for long-term care. The parent support ratio, which is the population 85+ to those aged 50 to 64, provides an indication of the support families may need to provide to their oldest members. Globally, there were less than 2 persons aged 85+ for every 100 persons aged 50-64 in 1950. By 2000, the ratio had increased to 4 per 100, and it is projected to reach 11 by 2050 [1].

- The current average spending in the healthcare sector as a percentage of its GDP, is increasing in all countries due to increased old age persons. This rise in healthcare costs is affecting the economic growth of countries.

- Health information must be made available to the health care ecosystem through ICT. WHO has recognised the importance of mobile health (mHealth) as the medical and public health practice supported by mobile devices like smartphones, tablets, patient monitoring systems etc [2].

- Smart wearable devices and smartphones are increasingly being used for healthcare applications as they can provide the function of medical sensor and transmit body parameters of the patient in real time for analysis and corrective actions.

- The purpose of the smart wearables is to monitor health of the user while being worn by the user on the body. The recorded parameters can be stored on the memory embedded in the design or transferred to the Aggregation manager. Some examples of smart wearables used today globally are pedometer, Wearable ECG Device or Patch, Pulse-Oximeter, Heart-Rate monitors, Smart Glasses and Smart Watches.

4.2 Demand Drivers

Let us first look at the various entities/players involved in the healthcare ecosystem. The table below lists out the same.

Entity	Description
Patient	The person whose vital parameters are to be monitored and healthcare delivered either routinely or in a emergency condition like heart attack, accident etc.
Personal Device (Sensor) or Patient monitoring devices	Interfaces on one side with the physical world, measures patient's vitals (BP, Blood Sugar, ECG, Weight etc) and Interfaces with a Medical Gateway at the other side. This interface could be either wired (Serial, USB) or wireless (BT, Zigbee) and these devices may either be single or multi parameter monitors. They may either use a proprietary protocol to communicate with the Gateway or a standard protocol.
Medical Gateway	The Device that interfaces with the personal devices at the patient's location, aggregates the information and communicates with the backend system (EHR / PHR/CIS). This Gateway could be a dedicated hardware-based device, or software on a PC or mobile device.
Communication Infrastructure (backbone)	This infrastructure forms the backbone of Remote Patient monitoring system. It can be telecom infrastructure or devices communicating over a dedicated one-to-one communication between Ambulance and Hospital
Medical Records	The Database at the back end (Could be an hospital based EMR, a Public PHR or any type of Clinical Information System
Remote Patient Monitoring Application Platform	This could be an Application Framework that leverages the Medical Records information and provides the Care-Provider a customized interface depending on the end-application.
Tele health Care Provider	Including doctors, nurses and other telehealth staff (can be paramedics) who are involved in monitoring the vitals, evaluate the information. Paramedics are in ambulances and provide the emergency care.
Clinician / doctor	Including doctors / clinicians who can intervene based on data and feedback from telehealth care provider, to take appropriate action for the patient.
Ambulance management system	A centralized emergency management system which controls the despatch and movement of ambulances and also has the necessary emergency care provision system inside the ambulances.

Table 4.1: Entities involved in the healthcare system

4.2.1 Consumer Demand Drivers

The main driver is the cost and ease of delivery of healthcare. It is required to transition from the present model of specialist driven hospital-based system to a patient centred care model with remote delivery of healthcare services. The current centralized hospital cost model includes number of beds, length of hospital stays etc amongst other things. This could be shifted to a decentralized model, where treatment could be carried outside the centralised hospitals. This could include treatment at homes, day surgeries/ clinics, smaller nursing homes etc.

In highly populous countries like China and India where diabetes and asthma are prevalent, the outpatient numbers in hospitals could become unmanageable. Therefore, it is required to implementing strategies to virtualize healthcare to curb the demand for face to face health services in hospitals. It is required to empower patients, their caretakers, and any other lesser qualified professionals to manage personal healthcare. Consumer demand greater convenience and freedom of choice with respect to healthcare like not waiting in long queues or appointments for doctor consultation or hospital treatment. They would want immediate secure online consultations and diagnosis and treatment.

We have seen in the earlier section that the aged population is increasing rapidly, and this calls for an additional care of aged and elderly at their homes itself. It is difficult for them to go to a hospital or a doctor for health check-ups and treatment and it is required to provide healthcare to them at their place and convenience. This is one of the most important demand drivers for remote healthcare.

Some of the Connected health scenarios which needs to be addressed, are below. This is extremely important for Elderly care/ assisted living

- Routine health check-up by remotely monitoring parameters like blood pressure, diabetes, ECG etc.
- Transmission of alerts if certain vitals reach dangerous levels. Sleeping patterns to be monitored.
- Detection of fall of aged people and instant alert to nearby caregiver or ambulance for quick response. This scenario normally happens when they try to get out of the bed or in the bathroom.
- The system should keep track of the personal medicines to be taken and should alert the patient at the specific time. The reminders can be managed locally also by a Smart-phone App or other mechanism. However, usage of medicines needs to be recorded.
- Home Dialysis is an important requirement in advanced diabetic patients and reports can be generated for remote monitoring and consultancy.

Consumers should have the flexibility to choose where and how to obtain healthcare services. They would require access to healthcare anytime and from anywhere by online or through mobile phone. They should have the ability to share their medical records with different healthcare providers.

Remote patient monitoring enables patients, caregivers, and their family members to take a more proactive role in managing their health and is becoming increasingly prevalent in the healthcare industry. It further enables patients and their family members to track vital information like blood pressure, weight change, glucose levels and other vital signs while eliminating a majority of "unnecessary data noise" that does not warrant a clinical intervention.

4.2.2 Business Demand Drivers

Governments Health care systems are burdened with people with multiple chronic diseases, especially with elderly. Better management of the elderly and their chronic conditions is not a nice-to-have but a must-have requirement. Hospital care to home care transition has a huge cost saving benefits to governments. Therefore, homecare becomes essential requirement. Health care providers like hospitals or doctors, should be able to access the patient anywhere and at any time and provide healthcare. The access mechanisms could be through on-line, telephone consultations, tracking of parameters through sensors on the patient etc and should ensure privacy and security.

Proper medical/ first aid needs to be ensured during ambulance travel for treatments of patients in emergency conditions. Identification of patients and accessing their electronic health records should be made possible. Ambulance paramedics should be able to connect on-line with hospital doctors, to be able to provide the right type of treatment while in transit. The ambulance movement should also be connected to the road-traffic management system, so that traffic signals can be managed to facilitate a non-stop movement of the ambulance to the hospital. In cases, where it is not possible to get the patient for surgery at a speciality hospital, there should be facilities for conducting assisted remote surgery.

Governance related:

- Interlink healthcare with social security benefits
- Track hospital assets – This requires scalability of connectivity in terms of number of connected devices as there would be tens of thousands of objects needing to be monitored with more precision accuracy as they would be located in any part of a large hospital. Access technologies may be different in various areas of in and outside of the hospital. This could also include ambulances and medical helicopters on the move. The connectivity should ensure seamless handover for good continuity.
- Allow flexible sharing of patient information with different healthcare providers in terms of emergency or with consent of the patient.
- System should be economical. easy to use, as otherwise it would inhibit the implementation of remote health systems. Clinicians are deterred from or resistant to using new systems that adds complexity to their workflow or requires additional effort or time. In the case of an e-Health

system supporting physician-patient interaction, an effective clinical decision support system must minimise the effort required by clinicians to receive and act on system recommendations. This requirement is extended to include ease of use for patients and their family members and other service users, or even health professionals besides clinicians, such as nurses.

4.3 5G as a Technology Enabler

5G is expected to allow connectivity speeds of up to 10 gbps– providing parity with wireline speeds. It will also include the ability to support large number of devices and enables ultra-reliable low latency communications. Some mission-critical medical functions require high reliability and availability with latency intervals that are down to a few milliseconds. 5G will make this possible and bring consistent, reliable user experiences to improve medical care. The high bandwidth, high QoS, ultra-low latency and lossless video compression offered by 5G is enabler for Healthcare. 5G networks will open new opportunities for the delivery of healthcare, by connecting patients and healthcare providers across the world enabled by the connection of medical devices. Digital images can be shared with specialist globally for analysis and advice. Wearable and embedded devices can transmit vital parameters to doctors and alert them for emergencies.

It is expected that the future healthcare systems would connect billions of low-energies, low bit rate connected health monitoring devices and sensors. 5G will enable this with its greatly enhanced eMBB data rates and hyper connectivity. 5G's eMBB feature will also support personalised healthcare applications and immersive experience such as VR and live video streaming. This enables doctors to administer remote care through 3D/ UHD video telepresence or UHD video streaming,
The 5G New Radio unified air interface is designed to deliver deep, redundant coverage and high system availability to connect medical sensors across multiple network nodes. This boosts reliability (1 out of 100 million packets lost), minimize latency (as low as one millisecond), and ensure that critical transmissions, such as medical emergencies, can be prioritized over other transmissions. For example, a recent heart attack victim's 5G IoMT sensors could quickly transmit a distress signal and vital signs over the network to a nearby hospital, ensuring the rapid response of EMTs to administer care. Failure is not an option in this scenario as losing connectivity could result in serious consequences.

The 5G ecosystem also offers strong security solutions, such as the seamless and secure sharing of biometric data, to ensure that patient-sensitive data is safeguarded from exposure and risk. 5G allows biometric sensor data to be reliably captured, aggregated, and seamlessly transmitted to the cloud for integration with virtually any system, application, or portal for continuous monitoring from anywhere and anytime. This will enable doctors, hospitals, and other care organization to prescribe a wide variety of sensors and devices designed for near time data capture in patient's homes and provide personalized care [3].

5G technology could improve connectivity of IoT devices in the healthcare sector. The current Key Performance Indicators for the 5G infrastructure for the fully connected society, as discussed and highlighted in the 5G Vision whitepaper developed by the 5G PPP Infrastructure Association are sufficient to satisfy most of the technical requirements in the healthcare sector [4]:

- 1,000 X in number of connected devices reaching a density ≥ 1M terminals/km2
- 1/10 X in energy consumption compared to 2010
- 1/5 X in end-to-end latency reaching 5 ms for e.g. tactile Internet and radio link latency reaching a target ≤1 ms for e.g. robotic assisted surgery
- 99.999% aggregate service reliability for safety-critical services
- Mobility support at speed ≥ 500km/h for ground transportation
- Accuracy of outdoor terminal location ≤ 1 meter

The advances in Network Function Virtualization (NFV) and Software-defined Networking (SDN) have increased the ability to flexible allocate computing resources within the network.

5G New Radio interface and access extends beyond those of previous generations of mobile communication, with massive system capacity, extremely low latency, ultra-high reliability and availability, and low device energy consumption. Network Slicing feature enables roaming of network slices in other networks to provide global reach for services. RAN virtualization and Distributed Cloud ensure extremely low end-to-end latency. AI and data analytics will become important elements of making the networks self-optimizing to secure the fulfilment of service-level agreements [5].

5G provides interesting characteristics from the point of view of protocols flexibility, being capable of managing a variety of local networks with specific protocols, including those with high energy efficiency. Besides, the 5G capability to manage a vertical roaming within a single session (with the terminal controlling the session) enables coverage that today's system has problems in providing [6].

5G enables remote robotic surgery by its < 1mS latency and high availability as minimal connection down-time is mandatory since ongoing surgery cannot be interrupted. Its peak data rate and its high throughput capacity can transfer HD image streams and its minimal packet loss ensure high reliability during surgery. Also, its high battery life ensures uninterrupted surgeries.

4.4 Socio Economic Impact

4.4.1 Social Impact

Several areas will emerge for operators to enter the healthcare value chain and drive its transformation, including hospital applications – VR used in medical training, telemetry, and online booking systems – and real-time medical data management. The area that holds the most promise for operators addressing this industry with 5G is patient applications used outside of traditional hospital environments. Examples of use cases in this category include precision medicine, online consultations, and applications to monitor health and administer medication remotely to better manage chronic ailments.
5G enhanced e- and m-health technologies will reduce disparities between urban and rural healthcare through ubiquitous access to health care anywhere, anyhow and at any time.

4.4.1.1 Remote Patient monitoring

We have seen in earlier section that the increasing aged population needing support, is challenging to the society. Also, illnesses which usually accompanies old age must be addressed, which would require large resources. Remote monitoring of patient could be implemented by using a Body Area Network (BAN) with wireless sensors, both on-skin and implanted. Sensitive parameters could be measured in real-time and reported to Doctor for immediate attention.

5G will support continuous monitoring and processing of numerous sensory devices, facilitating remote monitoring of patients and substantially increasing the effectiveness of preventive care. It can lower the burden of chronic diseases, through remote management, avoiding costly and unplanned hospitalization. Here, patient and carers get more empowered to manage their own care. Online consultations supported via 5G will reduce “painful” patient wait times. Connected health care supported by 5G will make better doctors and health care available to more people, regardless of location and 5G will make centralized patient records more accessible, leading to more efficiency and better outcomes.

The transition **to Home-based care system** will enable patients, caregivers and their family members take a more proactive role in managing their health. Remote patient monitoring also enables patients and their family members to track vital information like blood pressure, weight change, glucose levels and other vital signs while eliminating majority of the “unnecessary data noise” that is not warranting a clinical intervention and a hospital visit. Hence, Remote Patient Monitoring will become increasingly prevalent in the healthcare industry. Figure 4.1 illustrates remote monitoring of patients. Tele-care and telemedicine would provide new opportunities for providing medical care to the home, including ways of monitoring well-being and improving the medical information available to healthcare providers.

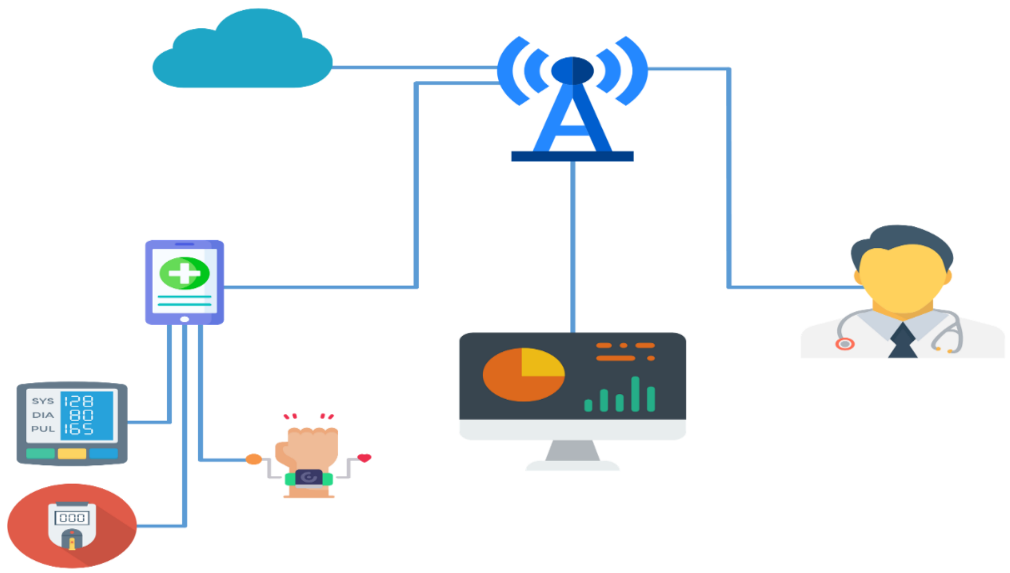

Figure 4.1: Remote Patient Monitoring

Tele-care can be administered through audio and video conference. Figure 4.2 illustrates telecare through video conference.

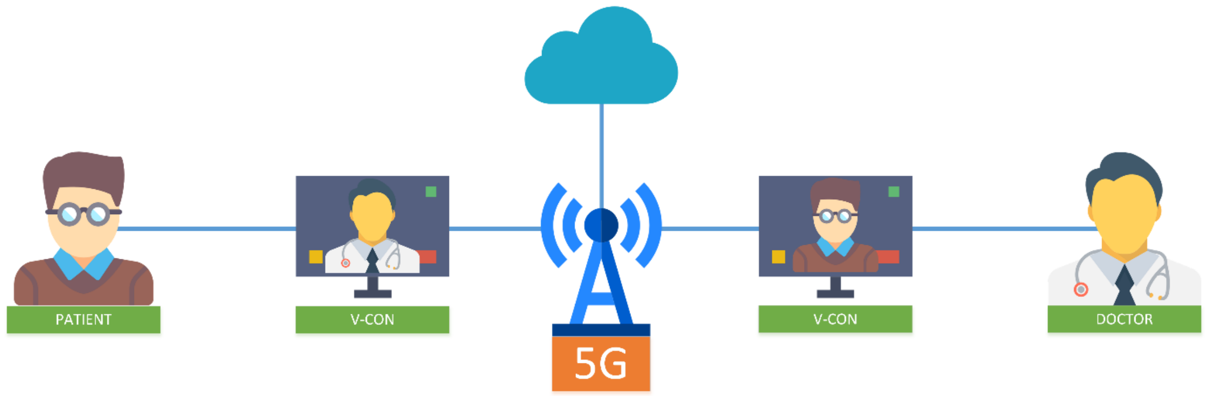

Figure 4.2: Telecare through video conference.

Disease prevention and lifestyle changes can be addressed by using of ICT. The healthcare system would be able to collect data from different sources and make it available to User and clinical professionals. Personalisation of the clinical profile can help in prevention by designing personalised medicine by the data collected from monitoring and the personal clinical history. Aged and elderly people population in increasing and they form high risk and high cost in healthcare ecosystem. Better management of this outside a hospital setting and in a preventive care manner will have a positive impact on lowering the healthcare costs. 5G technologies will enable new ways of delivering personalised healthcare and more effective and efficient therapeutic approaches. Human computer interface and behaviour change theories can be integrated in the design and development of m-Health applications. With the gathering of real-time psychological, physiological, and symptomatic patient data and inputs from healthcare professionals, patients can achieve a greater degree of autonomy, competence, and relatedness in self-managing their health and disease. It gives greater autonomy to people in the choice of healthcare and management through tele consultation. The personalization of health care enables health care providers to personalise patient's treatment. Information on the patients' environments, behaviour, emotional state and corresponding symptoms with vital signs such as BP and heart rate can be sent from the connected devices via 5G data link to the healthcare provider in real-time to prevent severe episodes. The devices can also be connected to social network to allow the patient to interact with their health eco system at anytime, anywhere, anyhow to selectively share personal data safely and securely via the associated knowledge management system. The instant exchange of information will enable formal and informal carers to advise the patient more appropriately.

4.4.1.2 Smart Medication

New pharmaceuticals embedding connected devices could be used for the treatment of Asthma, Diabetes and Multiple Sclerosis, and the management of chronic diseases and pains in general.

In US, this approach is well known as "Precision Medicine", which aims at collection of a variety of personal data leading to an individual pharmaceutical approach towards rather than applying estimated dosages of pharmaceuticals derived from statistical analysis of large groups or populations.

This will inevitably require the collection of a rapidly increasing amount of individual data on a day to day basis via sensors, embedded systems and cyber-physical systems quickly exhausting the available network capacities. This is enabled by 5G connectivity [7].

4.4.1.3 Tele Radiology and Imaging

5G will also have benefits in areas such as remote diagnosis and imaging by facilitating real time exchange of imaging data like CT Scan, X-Ray etc for specialist advice. In emergency care like accidents, enable instant retrievals of Patient EMRs stored in network and cloud, which can be lifesaving.

4.4.1.4 Robotics assisted remote surgery

5G enables remote robotic surgery by its < 1mS latency and high availability as minimal connection down-time is mandatory since ongoing surgery cannot be interrupted. Its peak data rate and its high throughput capacity can transfer HD image streams and its minimal packet loss ensure high reliability during surgery. Also, its high battery life ensures low uninterrupted surgeries.

- The requirements for cooperative active coordination are huge and needs ultra-reliable availability of information from backend databases and real-time data streams from a large variety of sources.

- Reduction in latency offered by 5G, would enable remotely assisted surgery. It is difficult to get specialists in remote places and they could assist the local surgeon remotely to perform certain procedures which requires expertise,
- Also, senior surgeons could assist junior/ trainee surgeons remotely.
- Live-in-robots can facilitate telemedicine to provide constant critical care to patients and provide support in assisting elderly people. With 5G connected robot, a doctor can give instructions for it to visit the patient's bedside. Using the robot's audio-visual teleconferencing feature, doctor and patient can interact and share medical information easily and naturally. Remote diagnosis allows a doctor to analyse symptoms from a distance. This is particularly advantageous for rural areas without medical resources nearby and for patients who are unable to travel to see a doctor.
    - Doctor Antonio de Lacy carried out the world's first 5G-powered tele mentored live surgery [8]. He provided a real-time guidance via a 5G video link as a demonstration at MWC 2019 from a Barcelona congress centre to a surgical team which operated on a patient with an intestinal tumour about 5 kms away in a hospital. During that operation, the 5G connection had a lag time of just 0.01 seconds compared to the 0.27 second latency with 4G networks.
    - Surgeon in the Fujian province of China has performed the world's first remote operation using 5G surgery on an animal. He used 5G connectivity to control robotic arms in a remote location 30 miles away to remove the liver of a laboratory test animal [9].

4.4.1.5 Other impacts

5G's enablement of continuous monitoring can be harnessed to its other attributes to even greater effect. While continuous monitoring will power the development of new data streams, the use of distributed computing—the processing of patient data nearer to the patient—will power predictive analytics and intelligent care based on those new data streams. Predictive analysis can help by letting know if any critical medical condition is likely to occur in near future.

5G will be an important element in the proliferation of data, and this proliferation combined with predictive analytics and machine learning will allow physicians and researchers to access aggregated information and accumulated knowledge on the latest evidence, diagnosis, and treatment trends. This will not only advance the state of medicine and health outcomes, but our understanding of the human condition itself. 5G will support application of virtual reality, which can have important benefits in the delivery of medical care, e.g., in the diagnosis and treatment of critical medical episodes such as strokes Some mission-critical medical functions require high reliability and availability with latency intervals that are down to a few milliseconds. 5G will make this possible and bring consistent, reliable user experiences to improve medical care.

5G also facilitates easy and secure access to an online central repository of medical records which can help in the management of the healthcare.

Figure 4.3 below, illustrates Smart Health Management enabled by 5G.

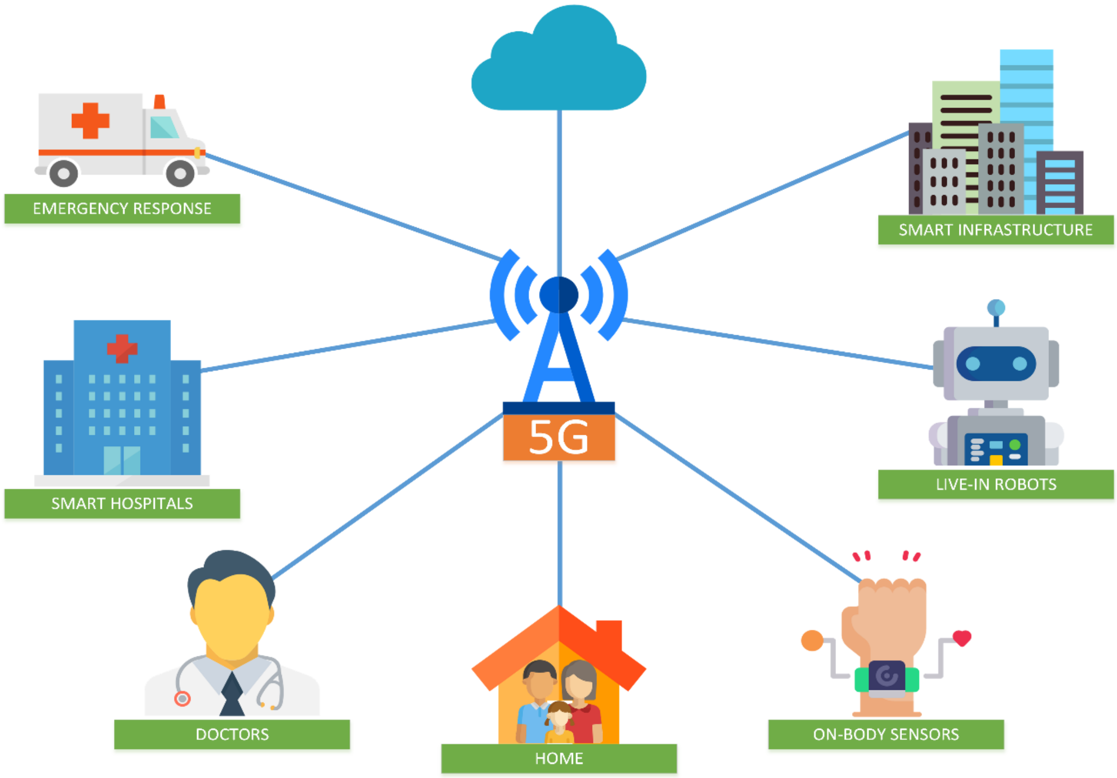

Figure 4.3: Smart Health

4.4.2 Economic Impact

- In an increasing ageing global population, homecare can result in a huge cost savings for the patients and the government's Medicare systems.

- Governments Health care systems are burdened with people with multiple chronic diseases, especially with elderly. Better management of the elderly and their chronic conditions leads to a large cost savings for the governments. Hospital re-admissions for elderly patients will be expensive and a burden on taxpayer. Transition from a hospital-based care system to a home-based care system has huge economic benefits for governments.

- The patient-monitoring wearable market, which includes remote and on-site devices, is expected to grow rapidly. According to a Qualcomm report, these devices will expand from 8 million shipments (from last year) to 33 million in 2021 and annual global IoT in health care revenues are expected to pass $27 billion by 2025 [3].

- Healthcare applications itself could have an economic impact of $1.1 trillion to $2.5 trillion per year by 2025 [10].

- Juniper Research suggests that over the next five years, remote patient monitoring alone will result in cost savings of up to $36 billion globally and that North America will account for little over three quarters of the savings [11].

- Ericsson predicts a USD 76 billion revenue opportunity in 2026 for operators addressing healthcare transformation with 5G [5]. This technological transformation of the healthcare sector offers numerous opportunities for telecom operators to penetrate new value chains and initiate partnerships that benefit the entire ecosystem. operators could provide system integration along with app and service development – in addition to their roles as network providers.

  Telecom Operator revenue potential in addressing healthcare industry digitalization with 5G
  - Patient applications – 49.2 Billion USD
  - Hospital applications – 19.8
  - Healthcare other – 5.2
  - Medical data management – 1.6

    Total: 75.7 Billion USD [5].

- Hospital will turn into data centres - For the transformation of patient applications to happen, patient data will need to be stored centrally, effectively turning hospitals into data centres and doctors into data scientists. Patients will get online access to a central repository of medical records to help them easily manage the quality and efficiency of their care.

- There will be a substantial impact of 5G on the all the entities involved in health care sector. 5G will be an enabler for a new era of “personalized health care.”

- The economic consequences of the personalization of health care are substantial. Better monitoring means a greater ability to reward providers based on outcomes not “volumes.” Better monitoring also shifts the locus of care to the home and similar lower-cost settings, and away from the hospital. Both these effects of better monitoring will help contain costs [12].

- Another big impact will be on the software industry in the area of Application development, as the Healthcare providers/ Hospitals will have to partner with them for development of applications to integrate wearable devices and/or develop Mobile Apps to harness the power of smartphones in health parameter testing.

4.5 Business Models

The current business model adopted by hospitals are centralizing or maximizing inpatient revenue streams. This will have to change to bringing in Home-based care, wherever possible. They must revamp the business models to remain competitive in future. Future business models and value chains should be flexible and adaptable to allow each stakeholder group to focus on its core competencies, such as delivery of care, sector application development, platform, infrastructure, or network service provisioning. Identified interfaces must be specified, between all potential business roles that could be performed by stakeholders within the same of different administrative domains.

'Smart Health Care' Business model

The author has defined the 'Smart Health Care' Business model based on the Seven Dimensions of Business Model [13].

Value proposition –

1) Home care through
    - Remote patient monitoring
    - Telecare
    - Smart Medication
2) Remote health care
    - Teleradiology
    - Robotics assisted remote surgery
    - EMR Accessibility

Customers or Users –

- Patients at homes
- Patients at remote places
- Patients in hospitals
- Hospital personnel

Value chain functions –

- Video conferencing
- Radiology
- Surgeries assisted remotely
- Surgeries assisted by robots
- Live-in robotic assistance

- Emergency response systems
- Critical care systems
- Delivery of care

Competences –

- Doctors’ and care givers’ competencies in devices and systems as applicable to them
- Advanced data analytics capabilities for predictive and prescriptive health care
- Hospital culture of adopting technology
- AR/VR systems

Network –

- Hospitals
- Home care providers
- Ambulance providers
- Advanced medical diagnostics equipment suppliers
- Medical robotics providers
- Communication service providers
- Pharmaceutical companies
- Insurance companies
- IT infrastructure companies
- Data analytics developers

Value formula –

- Direct payment by patient
- Cashless payment by insurance companies
- Part payment by patient and rest by insurance companies
- Full payment by employer
- Free service where government takes care of all costs
- Price transparency is important
- There will be a shift from in-patient revenue streams to home-based care revenue.

Relations – The integrated IT platform that links the hospitals, home care providers, medical equipment providers, pharmaceutical companies, ambulance providers, emergency personnel and patients either at hospitals or at their own homes.

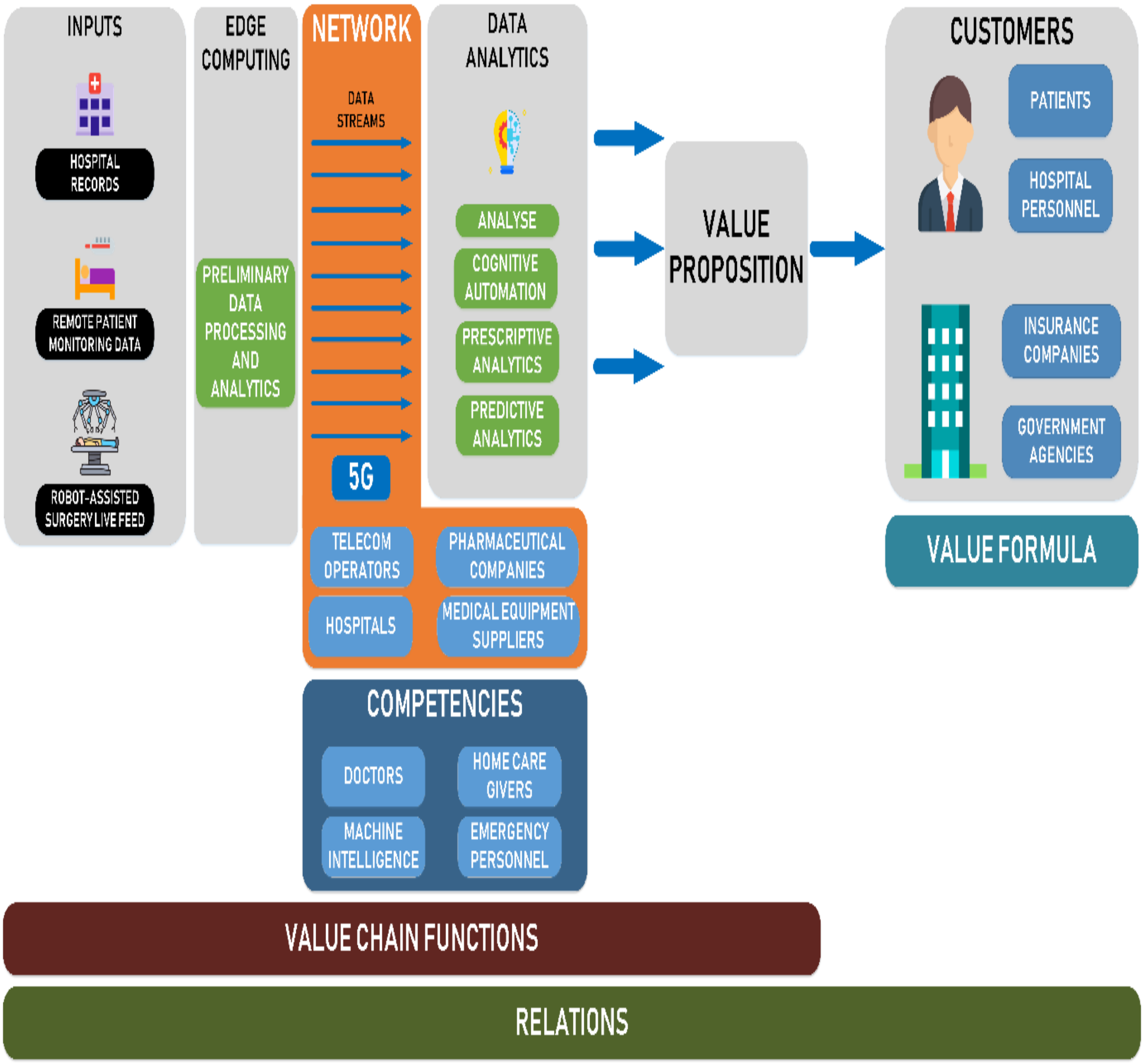

Figure 4.4: "Smart Healthcare" Business Model

4.6 Summary

Healthcare would be transformed by the advanced features of 5G supporting applications like remote patient monitoring, tele-care and telemedicine, tele-radiology, imaging, smart medication, robotic assisted remote surgery etc. This will have profound social impact as it provides home care to elderly and reduces disparities between urban and rural healthcare through ubiquitous access to health care anywhere, anyhow and at any time. This will also reduce government's spending on Medicare. Business model would shift from volume-based model to value-based care model and home based

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5.0 Socio-Economic Impact of 5G on Intelligent Transport Services

In this chapter, the concept of Intelligent Vehicles is first explained. The global trends in this domain are explored. The demand drivers for the Intelligent transport services, including requirement of consumers, businesses, and regulations, are analysed. The features of 5G in meeting the demands, are discussed. The socio-economic impact on the Transport services is analysed. The business models that the Transport industry should adopt, are presented.

5.1 Introduction

Intelligent vehicles are automobiles which have the capability to understand the environment around them and act in response to that environment without much assistance from a human being. Connected Commuting, Unmanned Road Vehicles (URV) or Autonomous Vehicles (AV) and Unmanned Air Vehicles (UAV) are examples of Intelligent vehicles. They work with array of sensors which act as the eyes, ears and senses of a vehicle and create a digital image of the environment. This digital image is analysed in real-time and action generated to navigate the vehicle.

Traffic management systems implemented by the road authorities help in managing unorderly traffic. This can be helped further if vehicles have built in visibility into knowing what is happening around them and have the intelligence to take proper navigation action. Also, traffic management systems can have enhanced visibility of road conditions and vehicular movement, by having cameras on lamp posts and other locations along the road, feeding data in real-time to its control centre for analysis and action.

The intelligence built into the vehicles can have visibility into subscriber behaviour, context, and per-service performance and this supported by a highly reliable and fast communication network, can present a wealth of opportunities in the Intelligent Transport Services.

5.1.1 Connected Commuting

Here, the vehicles in the road co-operate with each other by sharing information, to ensure their safety. The technologies associated with this concept are also known as Co-operative Intelligent Transportation Systems, whose main priority is to ensure road safety.

Wireless communication is the key enabler for this and are categorised as:

- Vehicle-to-vehicle (V2V) - between vehicles on the road
- Vehicle-to-infrastructure(V2I) - between vehicles and surrounding infrastructure
- Vehicle-to-network (V2N) -between the vehicle and the command centre through the network

- Vehicle-to-everything (V2X) communication.

Collectively, the above wireless transactions are referred to as V2X communication

Advanced Driver Assistance Systems facilitates Connected Commuting by accessing situations faster than drivers as driver reaction time could be too long for certain situations. Currently, automakers are using cameras, sensors, and radar for driver assistance, which can also be used for adaptive cruise control and traffic jam assist that will lead gradually to autonomous driving. These technologies are getting more precise and enabling more complex detection of objects.

5.1.2 Unmanned Road Vehicles (Autonomous Vehicles)

Vehicles had been driven by drivers who would perform all the driving tasks. As the technology of the vehicles progressed, some driving assistance features were included in the vehicle design which helped the driver, but the complete control was still with the driver. Later, features like cruise control with automated acceleration and steering, led to partial automation. Now, vehicles are being designed to take control of driving and allow the driver to take back control of the vehicle, if required. Going further, the concept of autonomous driving is leading to the vehicle handling the complete driving function without any human intervention [1].

Automated vehicles shall be cooperative and connected vehicles. Connected vehicles technology will lead to the advancement of Automated Vehicles. Automated vehicles will have to rely not only on their own sensors, but also on those of other vehicles, and will need to cooperate with each other, rather than make decisions on their own. These trends pose significant challenges to the underlying communication system, as information must reach its destination reliably within an exceedingly short time frame – beyond what current wireless technologies can provide.

5.1.3 Unmanned Air Vehicles (UAVs or Drones)

A UAV is an aircraft without a human pilot aboard. UAVs are a component of an Unmanned Aircraft System (UAS) which includes UAV, payload, a ground-based controller, and a system communication between the two [2]. The flight of UAVs may operate with various degrees of autonomy – either under remote control by human operator or autonomously by on-board computers. A UAV is defined as a "powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload". Therefore, missiles are not considered UAVs because the vehicle itself is a weapon that is not reused, though it is also unmanned and, in some cases, remotely guided [3]**.** UAVs represent the integrated vision of communications, navigations, sensing and services.

UAVs typically fall into one of six functional categories:

- Target and decoy – providing ground and aerial gunnery a target that simulates an enemy aircraft or missile
- Reconnaissance – providing battlefield intelligence
- Combat – providing attack capability for high-risk missions
- Logistics – delivering cargo
- Research and development – improve UAV technologies
- Civil and commercial UAVs – agriculture, aerial photography, data collection

5.2 Global Trends

Road traffic accidents resulting in deaths and injuries, are a major problem in countries today, with the exponentially increasing vehicles on road and rapid urbanization. There were roughly 1.25 million road traffic fatalities worldwide in 2013 with another 20–50 million injured or disabled through traffic accidents as per the report of World Health Organisation [4].

There are multiple reasons for these accidents to occur. It could be poor driving skills of drivers, bad road conditions, bad weather conditions like fog, inefficient traffic management, fatigue of drivers, technical problems in the vehicle and so on. Many accidents are caused at road junctions or intersections, as it is not possible to know what is coming from the other side. Also, highways have merging lanes for traffic coming from suburban roads and this is a hazard as the fast-moving highway vehicles suddenly encounter slow merging vehicles coming from bypasses. In US alone, this has been noted as the cause for about half of all the road accident deaths [5].

As per 5G Americas, connected car shipments globally has increased annually from 7.5 % in 2013 to 75% by 2020. 92 million cars are expected to be shipped globally in 2020, out of which cars with connectivity is expected to be 69 million i.e around 75% of the total cars shipped [6]. This is shown in Fig 5.1

As per 'Secure By Design' (SBD) Automotive,

- 175 million new connected cars are forecast to be sold globally between 2016 and 2020,
- In 2020 alone, 30 million cars are expected to be sold with embedded connectivity.
- The market for Advanced Driver Assistance Systems (ADAS) in Europe, USA and China is expected to grow from Euro 5.2 billion in 2016 to Euro 12.5 billion by 2022.
- Over 40 vehicle manufacturers have now launched connected car services and integrated apps in one or more markets [7].

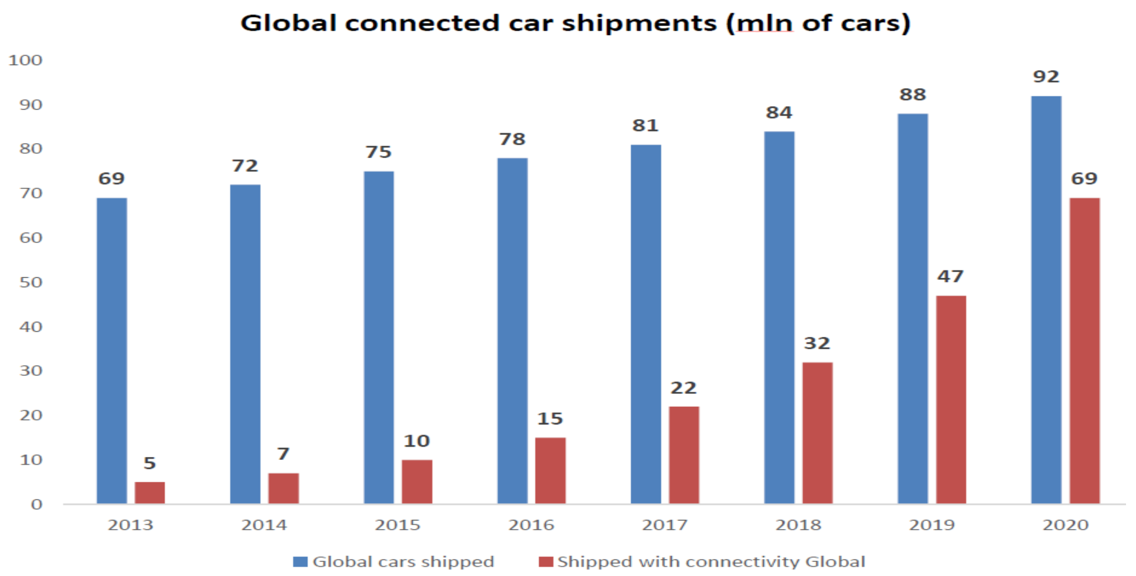

FIGURE 5.1: Global Connected Cars shipments (in Millions of cars)

Some of the Connected car services include safety, security, ease of navigation, convenience, infotainment, EV services, PAYD insurance, fleet management and electronic tolling. The table below shows different interested users of these services like the consumers, manufacturers, Government regulators and 3rd party users. It depicts the speed of adoption of these services by the different user groups. There had been a slow growth in adoption of these services till 2015.

Table 5.1 shows the expected speed of growth for each of the connected car services along with the key users who are adopting them. The key users include Consumers, Vehicle manufacturers, Government regulators and 3rd parties.

During 2015 to 2020, the forecast is that there will be fast growth of adoption for Services by different Users as shown in 'bold'. Example – Consumers and Government would be fast adopting 'Safety' services and so on. Some of the adoption for services would have become ubiquitous by Users as shown in 'bold italics'. For example, Navigation services would have become ubiquitous. Automobile manufacturers like General Motors, Ford and Fiat Chrysler are planning to introduce autonomous cars [9]**.** Vehicle manufacturers are realizing the true value of advanced driver assistance systems.

In the EU, USA and China, this fast-moving market is expected to grow from €5.2 billion in 2016 to €12.5 billion by 2022[7]. Revenue in the connected car market will amount to nearly $8.2 billion in 2017 and is expected to grow to over $18 billion by 2021 in the U.S. alone, according to research firm Statista. [10]

Many sources have reported different figures for the shipment of connected vehicles. The global trend can be inferred from these different reports. This trend shows the rate of adoption of connectivity in cars which is increasing exponentially with respect to the total cars sold per annum.

Between 2020 to 2025, more services would have become ubiquitous as shown in the table below.

Connected Car Service	MARKET TREND _ SPEED OF GROWTH/ DEMAND FROM		
	2010-2015	**2015-2020**	**2020-2025**
Safety	Consumers	**Consumers, Govt**	***Consumers, Govt***
Security	Consumers	Consumers, Govt 3rd Parties	**Consumers, Govt, 3rd Parties**
Navigation	**Consumers**	***Consumers***	***Consumers***
Convenience	Consumers	**Consumers**	**Consumers**
Infotainment	**Consumers**	**Consumers**	***Consumers***
EV Services	Consumers, Manufacturers	Consumers, Manufacturers, 3rd parties	**Consumers, Manufacturers, 3rd parties**
PAYD Insurance	Consumers, 3rd parties	Consumers, 3rd parties	**Consumers, 3rd parties**
Fleet Management	3rd parties	**3rd parties**	**3rd parties**
Electronic Tolling	Govt	Govt	**Govt**

TABLE 5.1: Market trend of adoption of connected services [8]

Speed of Growth: Normal font - Slow Growth; **Bold** - Fast Growth; ***Bold with italics*** - Ubiquitous

Researchers are exposing a growing range of threats to safety critical systems across multiple car brands. As cars become connected and autonomous, the risk and potential impact of a cyber-attack is growing. For the first time, hackers have the potential to compromise many vehicles with a single attack [7].

There is a global trend in associations and partnerships being formed between automobile, telecom, and technology companies to pursue the objective of Intelligent Vehicles. This is evident from the fact that leading automobile companies like Audi, BMW, Daimler; has come together with Telecom companies like Ericcson, Huawei, Nokia and embedded telematics companies like Intel & Qualcomm, to form 5G Automotive Association (5GAA). Their objective is to work together to develop end-to-end solutions for future mobility and transportation services. Since its inception, 5GAA has rapidly expanded to include key players with a global footprint in the automotive, technology and telecommunications industries. This includes automotive manufacturers, tier-1 suppliers, chipset/communication system providers, mobile operators, and infrastructure vendors [11].

Currently, automakers are designing vehicles with cameras, sensors, and radar for Advanced Driving Assistance Systems (ADAS) functions, which can also be used for adaptive cruise control and traffic jam assist that will lead gradually to autonomous driving. ADAS technologies are getting more precise and enabling more complex detection of objects. Use of real-time data are growing for ADAS. To share real-time data, vehicles must be equipped with embedded modems and wireless data connections. Real-time data can enable vehicles to run more efficiently, cut down on the emissions and potentially avoid accidents with other vehicles.

For the time being, connected features in the car largely operate independently of each other. There is the satellite navigation which may or may not be part of an audio and entertainment system. This may offer applications – typically music or games services – which require an internet connection. WiFi hotspots may be integrated but are often connected separately. Telematics services and devices used for usage-based insurance applications tend to be installed separately. Connected safety features such as cruise control, emerging braking, or semi-autonomous driving applications such as park-assist, do not hook into other functions.

Some vehicle manufacturers are developing computer algorithms to detect potential hardware problems and provide prognostic alerts. General Motors recently introduced OnStar Proactive Alerts. The service sends proactive alerts notifying customers of impending problems with the fuel pump, starter motor and battery for some GM models. Alerts are also sent to the dealer. When the customer takes the vehicle in for service the repair technician does not have to diagnose the problem and replaces the part faster. GM will introduce the service for models in the future [12].

With the race within the automotive industry to deploy vehicles with higher levels of autonomy, OEMs are accelerating their investments and developments towards autonomous vehicles. More than 20 manufacturers are aiming to launch such vehicles by 2020. Many trials of driverless cars are being conducted. Some notable recent trials are from Google, Uber, Tesla, Apple, BMW, Mercedes, and Volvo etc. Google has developed a police vehicle detection system for their self-driving cars. The detection system automatically detects police vehicles based on the pattern of flashing lights on the police cars. Once a police vehicle is detected, the self-driving car manoeuvres itself to yield to the police vehicle; for example, by pulling over to a side of a road. The system can also be used to detect other types of emergency vehicles such as ambulances based on ambulance light patterns.

In 2016, Uber self-driving truck had made a delivery of foods in Colorado, US, making a 200 KMs trip from Fort Collins through crowded city centres [13]. However, very recently, Uber's Self-driving car killed a pedestrian in Arizona, USA. This happened even with a back-up driver being available in the car [14]. This demonstrated need for a more robust communication system.

Unmanned Air Vehicles were originally used for missions which were dirty or dangerous to humans and were mainly confined to military applications. They are being used for military espionage and remote destruction of terrorist sites. However, now their use is expanding to commercial, scientific, recreational, agricultural, and other applications such as policing, peacekeeping, surveillance, product deliveries, aerial photography, agriculture etc. They are becoming extremely popular in taking videos in marriage functions, social functions, concerts, and public functions.

5.3 Demand Drivers

There are various requirements from Consumers, Vehicle manufacturers, 3rd Party Service Providers and the Government regulatory authorities with respect to Intelligent Transport Services.

5.3.1 Consumer Demand Drivers

Firstly, Consumers will expect to have mobile phone connectivity independent of their location and speed. There should not be any degradation of the quality of the connection during driving. This is a basic requirement.

Consumers demand safety as the prime requirement currently and in the distant future. Safety features will have to be mandatory and non-comprisable as the technology evolves towards connected and autonomous vehicles. Consumers also mandate easy and reliable navigation assistance to be integral feature of future vehicles. This is very much required in tough terrains and hazardous environment conditions, where alternate route advice guidance is expected.

Physically challenged drivers would require assistance by the vehicle taking control of some aspects of, or complete driving. Infotainment is a desirable feature now and would be expected to become mandatory in future. They would want, easy to understand and convenient systems in the vehicles. The features should be intuitive. Security is another major requirement, especially with the vehicle being to be monitored and controlled remotely. The demand is also for Electric Vehicles, so that environment can be kept healthy.

Vehicle insurance is expensive and experienced good drivers would want 'Usage based' insurance rather than 'fixed' as it is now. So, the system should be able to understand the driving experience, driving skills and driver behaviour. Good drivers want to be rewarded for their skills.

Connected Commuting Offerings should include

- Voice-activated alerts via mobile phone, warning of an upcoming traffic incident or public transport service disruption.
- Real-time web and app-based comparisons of multiple routes or transportation modes and how long they would take
- Recommended departure times to avoid being stuck in traffic and/or transport delays.

- GPS navigation visible on car windshield
- Carpooling is becoming a need in urban areas and applications should enable this.

5.3.2 Business Demand Drivers

Vehicle manufacturers are required to design more safety features into the vehicles to make driving safer which can help in reducing fatal road traffic accidents. This is a primary demand on them. New and enhanced services are required.

Autonomous driving, Connected Commuting and Advanced Driver Assistance Systems depend critically on predictive alerts because of the possibility of fatalities due to unattended faults. This feature is not only applicable for the vehicle hardware, but also important for the embedded software. Vehicle manufacturers should incorporate predictive alerts as a standard feature in designs and develop computer algorithms to detect potential hardware problems and provide prognostic alerts. The service should send proactive alerts notifying customers of impending problems with vehicle functions like the fuel pump, starter motor, battery etc. They should integrate this with their dealers, service centres and emergency care divisions, so that speedier problem identification and solution is made [15]. Since vehicles are networked, they could be susceptible for cyber-attacks. Hence, vehicle manufacturers should take precautions and always have the software updated, which must be done Over-the-air (OTA). OTA software updates can be challenging during adverse weather conditions. This would require an exceptionally good wireless communication system.

Fleet Management Companies demand fleet management services like asset tracking, route productivity, driver behaviour management, fuel optimisation etc, which demands embedded telematics with tracking solutions. The availability of data regarding the vehicle, can facilitate predictive analysis of the operation condition of the vehicle, which is required by them. There is increasing trend of consolidation happening in this space and fleet companies are now operating globally i.e. in multiple countries. The important driver for Fleet Management companies are cost savings and safety [16].

Insurance companies demand Pay-As-You-Use (PAYD) insurance or usage-based insurance. They want the driving of consumers to be monitored and fix premiums based on actual risks posed by drivers. Also, in case of accidents, they want to be alerted immediately by means of embedded telematics.
There is a demand for Electric Vehicles and all Manufacturers have to offer EVs in their future shipments. Third party Mobile App developers require to develop apps for shared commuting, which is becoming a consumer demand in urban areas. Transportation mobile app data should be used to advise transportation agencies on problem areas where infrastructure repairs or improvements are necessary.

Autonomous vehicle design should incorporate the following mandatory safety features:

- Parking assist in front and rear and parking assistance surround view, in rear.
- Emergency breaking and Collision avoidance
- Pedestrian detection
- Blind spot detection
- Surround view
- Traffic sign recognition
- Lane departure warning
- Adaptive cruise control
- Cross traffic alert
- Rear collision warning system

The business demand for UAVs are for:

- E-Commerce companies, for delivery of packages to customers, especially in remote areas
- Farmers, to put pesticides in their farmland
- Farmers, to check for disease infestations on top of trees (like coconut tress) where manually it is not possible.
- Inspection of dams and bridges
- Event Management companies, to video capture the event
- Political parties, to capture political rallies and functions.

Demand for UAVs will grow in all areas, as they become easier and safer to use. Ensuring safety is utmost so that they do not crash anywhere and are able to be properly landed.

5.3.3 Government Demand Drivers

Ensuring public safety is utmost important requirement for Governments with regards to Intelligent Transport services. This requirement mandates safety features to be incorporated in all vehicles. All vehicles should have security features built in.

Emergency call and response mechanisms are particularly important. Governments would want the system to handle emergency conditions like accidents, fires etc and be integrated into their Emergency response centre and hospitals to despatch ambulances or fire engines This requires integration of Vehicles with the Traffic Management systems.

Electronic tolling is another requirement enabling easy vehicles identification and management.

It is expected that the above demands are met, some applications will grow faster based on the importance and relevance of its demand like safety, navigation, and security features. Urban commuters are on the road for approx. 2.5 hours a day in major cities. This requires more fuel, increase carbon emission, and lowers productivity. This brings the requirement of Electric Vehicles. Governments are mandating use of Electric Vehicles s and even bringing out EV Policy. The state of Karnataka in India has brought out a comprehensive Electric Vehicle Policy.

Governments need UAVs for military and coastal surveillance applications. It is not possible to soldiers to handle certain tough surveillance functions. UAVs are required for this. Terrorists activities need to be monitored by UAVs. Postal departments also require UAVs to deliver in remote areas. UAVs will be very cost-effective for this. Forest departments needs UAVs for tracking forest area to detect poaching of protected animals, forest fires, smuggling etc. Geology department needs UAVs for surveillance of mining areas.

Table 5.2 below, summarizes the demand for application features of Intelligent Transport Services.

Feature	Consumer Demand	Business Demand	Manufacturer demand	Regulatory Demand
Safety	YES			YES
Navigation	YES			
Infotainment	YES			
Security	YES	YES		YES
Convenience	YES			
EV	YES	YES	YES	
Usage Based Insurance	YES	YES		
Electronic Tolling				YES
Fleet Management		YES		

Table 5.2: Intelligent Transport - Application feature demands

5.4 Technology Enablers

Currently, connected cars use a SIM card and the 4G network. LTE enables functions such as assisted parking and there has been a move towards "half automated driving" where a car can take over in certain situations without the driver's influence. Connected car today are centred around 4G, particularly Mobile Edge Computing. This enables latency of around 20 mS and hence does not enable real full automated driving. Connected cars should have the feature to get a warning is a car is coming at the back or if there is a road accident.

5.4.1 5G Technologies

5G technologies are the next generation of wireless networks. It is key to transmitting larger amounts of data more reliably, with lower latency and at faster speeds than ever before. As the future of connected devices, it will pave the path towards innovative ways of communication and will change our transportation ecosystem, the Internet of Things, and ultimately help create the Internet of Everything.

Intelligent transport systems including connected cars, autonomous vehicles and UAVs will become a possibility due to the connectivity features offered by 5G. This would enable the vehicles to communicate with each other, with infrastructure, with everything in the world around them. 5G can also add special features inside the car enhancing the passenger experience. The automotive industry can utilize the new services, applications and functions enabled by 5G and grow rapidly.

With 5G, the roadmap is starting with assisted driving moving towards fully automated driving, with its single digit latency and 100% connection availability. In addition, 5G will enable specific components and software to connect things at the most appropriate place and time. This will allow vehicle to talk to others around it. Also, 5G will be able to handle many connections and management of these. For e.g., 100s of cars in a small area will be sending data to the network every millisecond which will have to be processed in real time at the edge and made available to other cars. The application will have to give the guidance to cars on how to behave i.e. what to do. The network application sitting on the top of that needs to orchestrate all the vehicles on the road. This is a massive task and needs 5G as the current 4G is not scalable enough.

5G characteristics that will support Automotive industries use case, include:

- Bandwidth and device connections: to support high data volumes and service increasing number of devices connected to wireless networks, traffic monitors and sensors.
- Ultra-low latency: for applications such as driverless cars.
- Always-on connectivity: with ultra-high reliability requirements for driverless cars and traffic monitoring, 100% geographical coverage is also required to support an intelligent traffic monitoring and management system and driverless cars.
- Ultra- low latency to the order of 1mS.

Among its benefits, 5G can enable fully autonomous vehicles that can connect to the network in real time. Soon, this will be key in accident prevention and warning drivers of danger ahead. It will also offer vast improvements to in-car entertainment, giving users the ability to stream video on the move.
5G allows an immersive entertainment experience in the car. Meanwhile, it will also be able to tell fuel requirements and if something happens, your car can apply brake in advance. Taking this into account, the car industry is realising 5G will be key in Connected Vehicles.

The 5GAA forum also supports the idea that 5G will be the ultimate platform to enable co-operative Intelligent Transport Systems and the provision of V2X. 5G will be better in the ability to carry mission-critical communications for safer driving and further support enhanced V2X communications and connected mobility solutions. With the support of leaders from the automotive and information and telecommunications industries, 5GAA is paving the way towards a world of innovative mobility.

The V2X technology is already available but to support the autonomous vehicles of tomorrow, the technology must evolve to meet more demanding safety requirements. 5G will facilitate this evolution. It is extreme throughput, low latency, and enhanced reliability will allow vehicles to share rich, real-time data, supporting fully autonomous driving experiences. As the data pipe gets bigger and faster there will be more opportunities for real-time data. Real-time data can also be used to improve automotive performance.

5G is key to the evolution towards autonomous vehicles that will transform the driving experience.

5.4.2 Multi-Access Edge Computing in 5G Networks

Network systems are essential to the future of commuting. Multi-access Edge Computing (MEC) is a key enabling technology which enables hosting of applications in 5G access networks and supports critical applications and use cases. It supports compute and storage capacity at the network edge rather than in a cloud or a central data centre. Since processing is done at the edge of the network, it will provide significant applications benefits in terms of speed, reliability, and security. MEC platform can rapidly process content at the very edge of the mobile network, delivering an experience that is ultra-responsive as latency is significantly reduced. This reduces network congestion and enhances application performance as the processing of the tasks are done closer to the user. Several integrating technologies like Software Defined networking (SDN), Network Function Virtualization (NFV) and Network Slicing help in the implementation of Multi-Access Edge Computing.

MEC utilizes NFV infrastructure. NFV uses software-based approach to manage core networking functions through virtualization. MEC and NFV are used together in a 5G environment to increase compute capacity to meet increased networking demands. The NFV infrastructure may be dedicated to MEC or shared with other network functions or applications. The infrastructure and infrastructure management of NFV can be reused to the largest extent possible, by hosting both Virtual Network Functions (VNFs) and MEC applications on the same platform, thereby enhancing the computing experience. Scalability of MEC application can be enhanced by NFV's dynamic scale up/down capability of network resource depending on demand. MEC and NFV integrated network architecture supports low latency mobile multimedia applications and the Use cases include mobile game, high speed HD video streaming and local content caching for AR.

Software Defined Networking (SDN) proposes to transfer the control functionality to software-based entities and thereby eliminates the use of vendor specific black-box hardware. This puts a demand on data plane devices to communicate frequently with the SDN controllers. Thus, SDN controllers are located closer to the data plane to reduce the latency in packet processing. MEC offers the opportunity to locate control functions closer to data plane devices. MEC complements SDN ensuring highly efficient network operation and service delivery. SDN can be also used to make MEC more flexible and cost-effective for 5G applications.

Network slicing proposes a way of separating the network into different network segments. Thus, it allows multiple logical network segments to be created on top of a common shared physical infrastructure. Future IoT will enable a wide range of different types of connections and services. These connections and services will need performance guarantees as well as security. Network slicing can satisfy these requirements. Moreover, 5G mobile network will support both MEC and network slicing technologies. To support massive IoT systems, the network should be able to satisfy requirements such as massive cost reduction in communication, network scalability and edge analytics. The integration of MEC with Network slicing can be used to satisfy some of these requirements such as scalability and edge analytics. The key requirements to enable critical communications are reduced latency and traffic prioritization. While MEC can be used to reduce latency, network slicing can support traffic prioritization. Network slicing can be used to divide the MEC resources into different slices dynamically [17].

MEC is evolving into a key building block in the evolution of mobile-broadband networks complementing NFV and SDN and is identified as a key enabler for IoT and Mission-critical, vertical solutions. MEC is widely recognized as one of the key architectural concepts and technologies for 5G. MEC system and 5G systems can collaborate in traffic routing and policy control related operations as per 3GPP 5G system specifications [18]. The 5G system specification and its Service Based Architecture (SBA) leverage the service-based interactions between different network functions, aligning system operations with the network virtualization and Software Defined Networking paradigms. These very same characteristics are shared by MEC specifications. [19].

MEC finds applications in large public venues, where content can be delivered to consumers in the venues through its server located at the venue and this avoid large backhaul traffic to centralized server. Some of the Use cases enabled by MEC in 5G network would be Connected vehicles, AR and VR applications as they benefit from the low-latency, high-bandwidth and high availability [20]. The MEC application operates as a roadside unit for vehicle-to-infrastructure (V2I). Road hazards can be recognized, and warnings can be sent to nearby cars with extremely low latency. It enables a nearby car to receive data in a matter of milliseconds, and the driver to react instantly [21].

Nokia and its partners demonstrated how MEC can be used for V2V and V2I communications in a live LTE network. Vehicles connected via the distributed cloudlets based on the Nokia MEC platform received information such as warnings from other vehicles almost in real time, which is particularly important for traffic safety applications. Communication between Cars and a central cloud has an end-to-end latency of > 100mS to a Second. Base stations with a distributed MEC cloudlet show an end-to-end latency of below 20mS [22]. Adding MEC and applications to 5G base stations makes much faster communication. MEC is an enabler for optimized infrastructure investments and the first step towards 5G and autonomous driving. MEC is acknowledged as important for meeting the demanding low latency and bandwidth efficiency requirements of 5G [19].

MEC based Vehicle-to-Cloud solutions provides different services to help driving like HD real-time Maps, real-time traffic monitoring and alerts and richer passenger experience. It will support vehicles to drive co-operatively by giving indications of road hazards [23].
MEC will create new opportunities for Mobile Network Operators (MNOs) and Application providers in the domain of Augmented Reality and Video Analytics. New Business Models can emerge as below:

- Vehicle manufacturers monetize application providers for services to passengers and passengers directly for personalized services.
- Communication Service Providers monetize from vehicle manufactures for using the cloud.
- MNOs monetize the use of network by application providers.
- Application providers monetize vehicle manufacturers for provision of applications like HD maps, VR applications etc.
- Vehicle manufacturers monetize the users for all services provided.

Apart from above, drivers in connected vehicles share road hazards information with vehicles in non-line of sights in a mutual way.

MEC empowers traditional cloud computing to deploy advanced i.e low latency automotive use-cases by migrating automotive applications at the network-edge. The relevance of MEC is very high in the following use cases: [24]

- In assisting at intersection movement – it can warn host vehicle driver of collision risk through an intersection
- Real-time situational awareness & high definition maps – alert host vehicle of hazardous (eg ice) road conditions ahead.
- See-through - Provide host vehicle driver with a video stream of the view in front of remote vehicle intended to be passed using the oncoming traffic lane.
- Co-operative lane changes of automated vehicles – signalling by the host vehicles to, at least, one remote vehicle, of the host vehicle driver's intention to change lane to the remote vehicle's lane.
- It detects Vulnerable road user (VRU) in the vicinity of host vehicles and warns their drivers.

It can also Deliver and manage automotive software updates, though the relevance is low. 5G in combination with MEC technologies is expected to offer the capability to deliver Automated Driving and infotainment capabilities.

5.5 Socio Economic Impact

As vehicle manufacturers are adopting sensor technology for monitoring the various parameters of the vehicle, data generated may be used by the manufacture/ Vehicle owner/ user/ insurance provider (Pay as you drive) / Government, as per their requirement. Many types of applications would be expected during the transition to fully autonomous vehicles, some of which may be demanded faster by the stakeholder like the consumer/ the vehicle manufacturer/ the government or 3rd party service provider.

5.5.1 Connected Commuting

5.5.1.1 Social Impact

5.5.1.1.1 Connected Vehicles

Vehicles with embedded telematics enabled with 5G, can communicate with each when they are close during a travel. This gives rise to many useful features to the consumers. Figure 5.2 below depicts a scenario of connected vehicles.

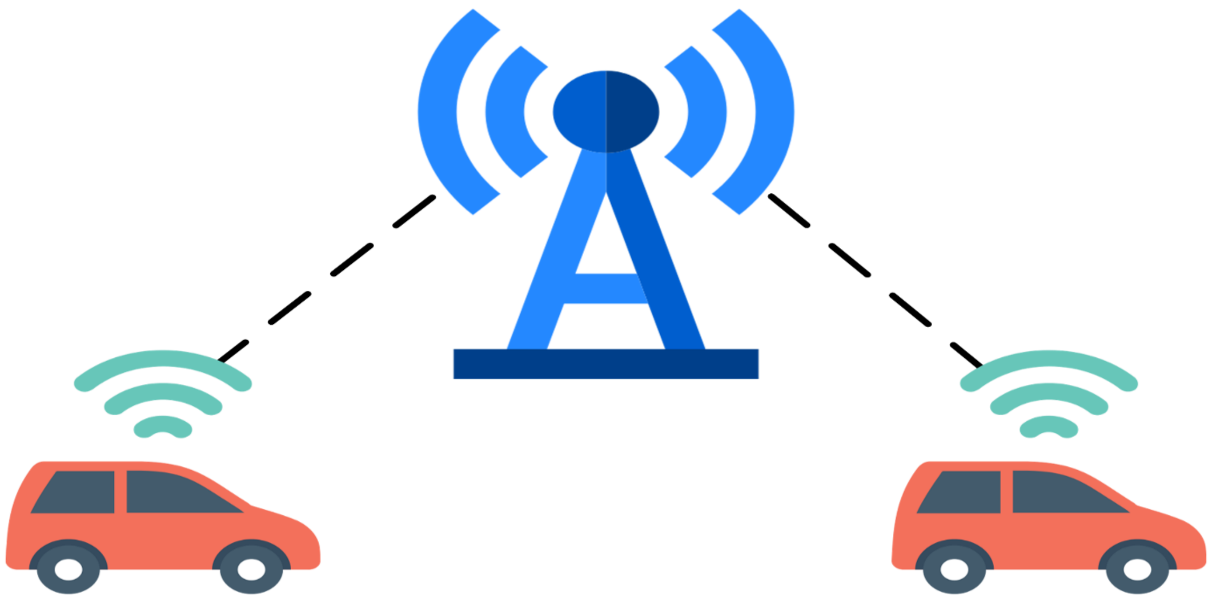

FIGURE 5.2: CONNECTED VEHICLES

The possibilities of connected commuting are as follows:

- Vehicle-to- Vehicle (V2V) communications comprises a wireless network where automobiles send messages to each other with information about what they are doing. This data would include speed, location, direction of travel, braking, and loss of stability.
- Vehicle-to- Infrastructure (V2I) communications comprises a wireless network where automobiles exchange messages with roadside installed infrastructure or satellites, with information about what they are doing. This data would include speed, location, direction of travel, braking, and loss of stability.

5G technology with its specific potential feature of low latency, can enable such communication. Figure 5.3 shows such a scenario.

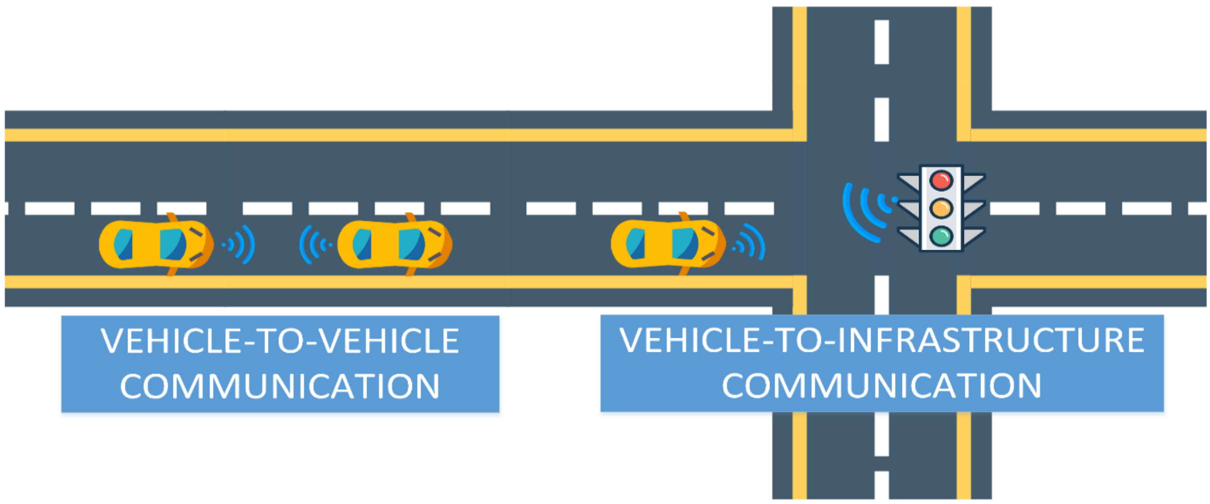

FIGURE 5.3: V2V and V2I Communication

5.5.1.1.2 "Vehicle Collision Avoidance"

Road accidents, caused by roadway departures and intersections, can be significantly lowered by deploying local warning systems through vehicular communications. Departing vehicles can inform other vehicles that they intend to depart the highway and arriving cars at intersections send warning messages to other cars traversing that intersection. Automatic braking when the car detects an obstacle will also likely reduce a significant number of rear-end collisions. Status information (e.g., position, speed, acceleration, etc.) or event information (e.g., traffic jam, icy road, fog, etc.) of individual vehicles can be sent to neighboring vehicles, or sent to a central point (base station, backend) where it can be aggregated and then again disseminated to other vehicles to make use of it.

- **Rear End Collision Avoidance:**

Warning can be given when approaching a vehicle which is slowing down or stopped. Also, while approaching a parked vehicle which is not visible due to obstructions.

- **At Intersections:**

Vehicle collisions during intersections can be avoided by collective knowledge through collective perception. This is also termed **"Bird's View".** This would enable vehicles to see through obstacles (buildings, other vehicles, etc.), get a bird's eye view of intersections or assist vehicles in finding a merge point on the highway. Status information (e.g., position, speed, acceleration, etc.) or event information (e.g., traffic jam, icy road, fog, etc.) of individual vehicles are sent to neighboring vehicles, or sent to a central point (base station, backend) where it can be aggregated and then again disseminated to other vehicles to make use of it. This would enable vehicles to see through obstacles (buildings, other vehicles, etc.), get a bird's eye view of intersections or assist vehicles in finding a merge point on the highway. Figure 5.4 shows this scenario.

- **During Lane changes:**

Blind spots are a big problem during lane changing. Blind spot warning could be extremely helpful during lane changes.

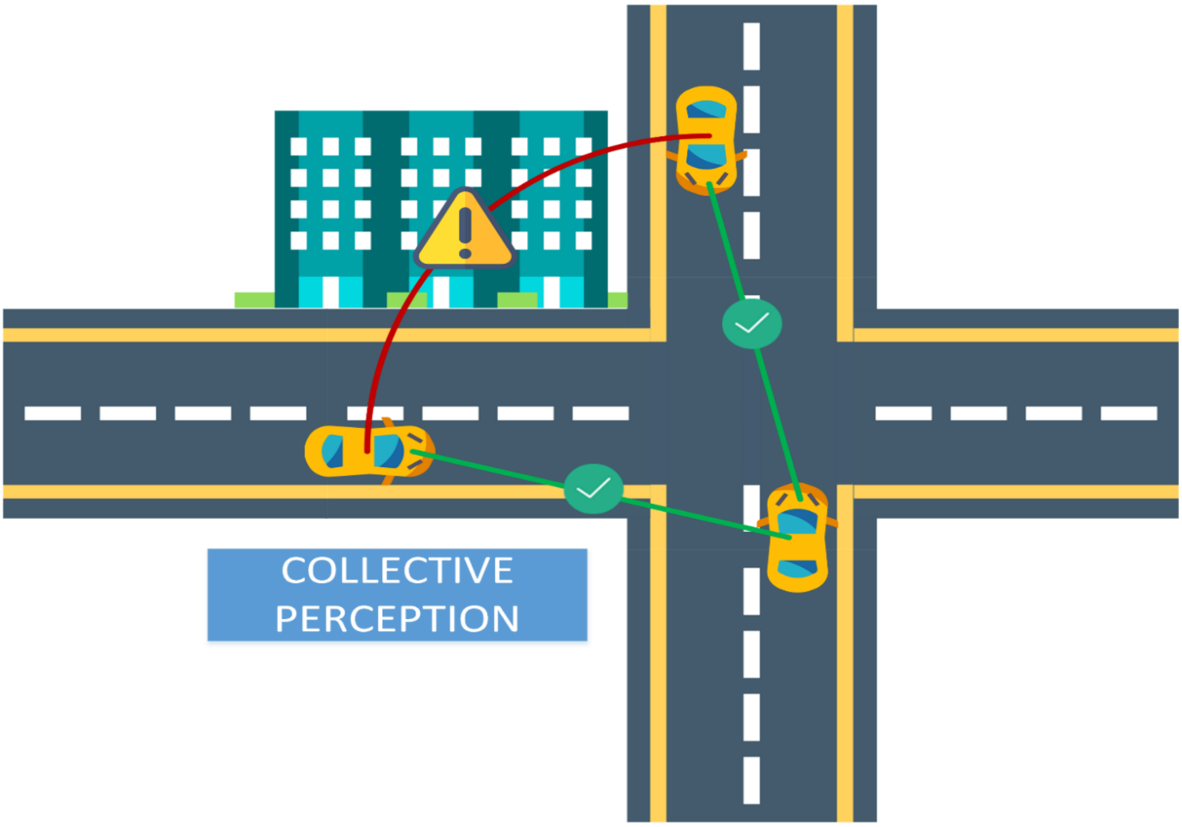

Figure 5.4: Collective Perception

5.5.1.1.3 "See Through Front Vehicles"

There could be numerous scenarios while driving, where it is advantageous to know what is in front of your vehicle-in-front, to be able to prepare for any eventualities. These use cases require a very high reliability and availability (it should work even out of coverage and even if the network is loaded with other services), a very low latency and a high data rate to share all relevant data with vehicles and pedestrians in the neighborhood. 5G could address this and enable such use cases.
Example: A car is behind a truck. Suddenly, a pedestrian is crossing the road in front of the truck. The truck camera detects the situation and shares the image of the pedestrian with the car, which sends the car driver an alert and shows the pedestrian in virtual reality on the windshield board.

5.5.1.1.4 Vulnerable road user (VRU):

VRUs (pedestrians, cyclists, etc., carrying a mobile device) discover vehicles in proximity and begin announcing themselves. The VRU mobile device may trigger a loud warning sound, vibration, flashing light, etc., in case of imminent danger. Vehicles in proximity of an announcing VRU notify both the driver and the VRU if a vulnerability situation is detected. One of the most critical issues with this use case is a reliable localization of the VRUs. Combining several positioning techniques – including satellite and natively integrated in 5G – should be able to increase the accuracy of the positioning, especially the relative positioning to vehicles in all environments (urban and rural).

5.5.1.1.5 Emergency call response

The system could use the driver's own mobile phone and activate the moment the driver enters the car. In the event of an accident, the system uses its hands-free phone capabilities to connect the driver directly with the emergency service number. Before initiating the emergency call, the system can provide a time window to allow the driver or passenger to decide whether to cancel the call. If not cancelled within the time window, the system can continue with the emergency call. The Emergency Response Centre can precisely know the location of the accident and can communicate with the driver. If the driver is unable to speak, it may know the nature of the accident from the inbuilt intelligence in the car and can connect with closest ambulance and despatch to the accident site. It can inform the nearby hospital also to expect the accident victim. It can be in touch with the car, paramedics in the ambulance to know the exact nature of the problem and can plan to shift the victim to the hospital attending that type of problems. Figure 5.5 illustrates Emergency Call Response.

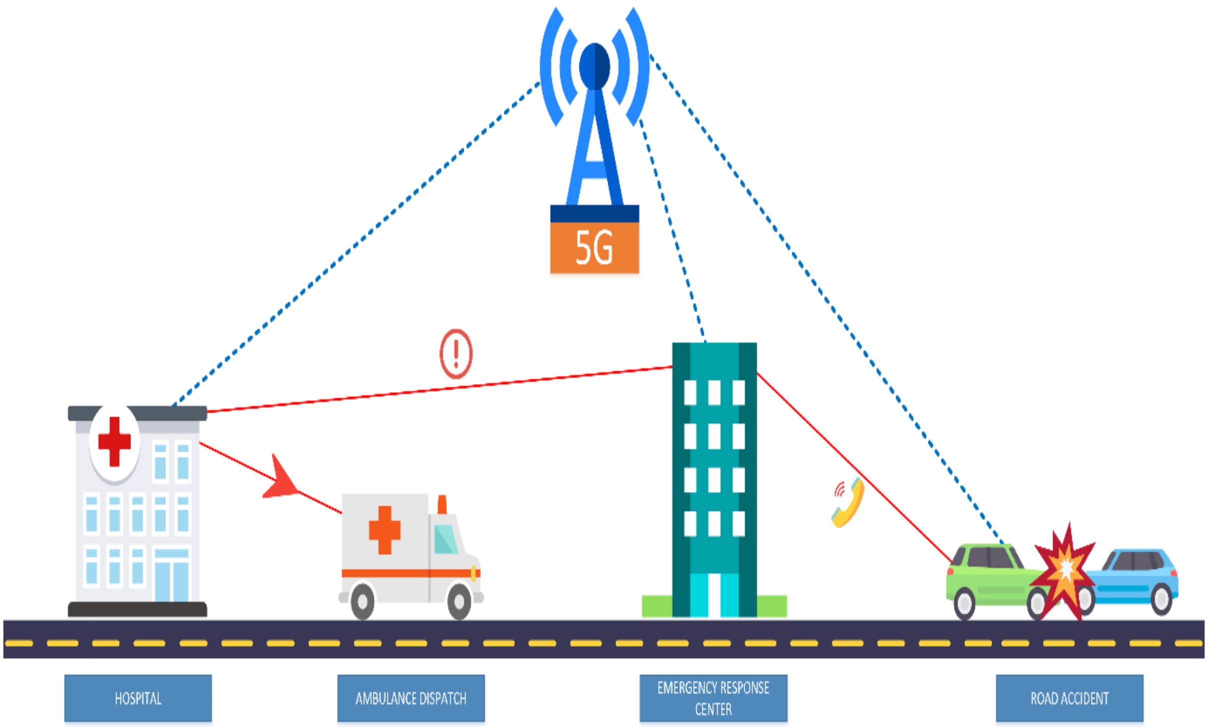

Figure 5.5: Emergency Call Response

Vehicle-to-Everything (V2X) will be important for both increasingly safety and for autonomous vehicles to become almost predictive rather than reactive. This combined with an increased use of radar should make our roads much safer.

5.5.1.2 Economic Impact

Connected Vehicle technology is a complementary technology that will lead to the advancement of Autonomous Vehicles. Telecom industry will be greatly benefitted from the growth of connected vehicles due to connectivity which is used in the vehicle. Connectivity can be through embedded telematics or user's smartphone integration. Embedded Telematics is more beneficial for the Telecom operators as it can provide M2M support to the vehicle manufacturers and applications like Billing, CRM, Device management and Network security. If only Smartphone is used for connectivity, it gives the Operators more data revenue due to greater consumption of data in the car but does not give any other revenue opportunity.

Automobile industry is impacted as the demands puts a challenge on its R&D, which will have to incorporate new features involving embedded electronics. Automotive industry expertise is basically in automobile and mechanical engineering. Now, they need Electronics and Communication expertise also. They may have to grow it in-house rapidly or collaborate with external partners for the same. They need to invest more now. Fleet Management companies would be the large users of Intelligent Transport services. Managing the fleet of vehicles with improved performance and enhanced safety and security is made possible by excellent connectivity. This will also present opportunities for them to consolidate with other companies and operate globally

We can see a great deal of collaboration happening between Telecom industry and Automobile industry. All the business stakeholders in this ecosystem namely -Vehicle manufacturers, Telecom providers and Fleet Management companies, would have huge amount of data availability and this can be monetized. Data is the new asset, and they can explore multiple ways to increase their revenues.

The transportation industry is slow to adopt disruptive technologies. The timeline for fully autonomous vehicles is unclear and complex, however, the technology benefits everyone. ADAS systems and partial self-driving systems reduce the severity and frequencies of crashes. These safety systems at current prices provide financial benefits for both the car buyer and society.

5.5.2 Unmanned Road Vehicles

5.5.2.1 Social Impact

Public safety is the real major social impact. It will be scary for the pedestrians, cyclists, and the vehicles of the road to see a driverless car going on its own. Even if there is minor glitch, it could result in fatal accidents. Glitches could be caused by bad road conditions or adverse weather conditions like heavy rain or snow, which can obstruct cameras and affect sensors. Even a sudden movement of a small animal crossing fast, may not be easily detectable. Criminals could easily alter a road sign to make the vehicle stop, so that they could rob the passengers. The privacy of the users is at total stake, as data is made available to many agencies. This also leads to the threat of cybercrimes. Cyber criminals could hack into the system and can completely take control of the vehicle.

In most of the developed urban cities, driving consumes a lot of time -approximately 2.5 hours a day. This is non-productive for the consumer and extremely stressful to drive in thick traffic. This leads to fatigue and body pain especially legs as they must constantly work on the pedals. Autonomous vehicles will be particularly useful as it will free up their time to do productive things during the travel and of course relieve them of driving stress and physical pains. A big problem in cities, is to find parking places near the destination. This could be a great irritant as one will have to go far to find a parking place and walk back to their destination. This can be resolved with Autonomous vehicles, which can drop the driver at the door of the destination and find a parking place on its own. Parking places in the office complexes of Central Business Districts (CBD) would be expensive and scarce. The Vehicle could find its own parking in a nearby place which is not expensive. This could save money for the consumer. The parking place owners in CBD could get lesser business with vehicles going far away for parking. With connectivity, the driver can locate where the car is parked and call it back when he/she is ready to go. It is just like a chauffeur driven car, minus the chauffeur. This would adversely affect the jobs and lives of chauffeurs, as they are being replaced by the intelligence in the vehicle. Ultimately, bus, truck, taxi, van drivers would lose their jobs.

Physically challenged people who find it impossible to drive on their own, would be greatly benefitted by Autonomous cars. The problems caused like drunken driving, over speeding, jumping traffic lights etc, could cease as Autonomous vehicles are programmed to follow rules. Therefore, accidents could be avoided and bring more safety to consumers. This would eliminate the need for taking insurance or the consumer will expect a lower premium based on usage. Since consumers are free of driving during travel, they would consume more media and cars can turn into living rooms.

Also, there could be problems caused by Driverless vehicles. Due to some faulty operations, it may cause accidents resulting in casualties. For example- Death of a pedestrian by an Uber self-driving car [12]. In March 2017, a self-driving Uber vehicle struck and killed a pedestrian crossing the street at night in Arizona, US. This happened despite a backup driver being in the car. This accident was attributed to the delay between vehicle’s sensing of obstacle and its response. Such incidents would cause fear in the minds of people when they see a driverless vehicle on the road. This would result to public protest against such vehicles. Waymo, a self-driving technology company of Alphabet (which owns Google) faces severe public protest during their trial run in Phoenix. There have been more than 20 documented physical attacks on these vehicles [25].

5.5.2.2 Economic Impact

People and companies may stop owning cars and may start to use mobility services. Fleet management companies will adopt this faster as they can overcome labour shortage and will not have any problems of the labour union going on strike etc. These vehicles can do the job 24x7 and 365 days a year (apart from servicing duration). This could potentially increase efficiency, productivity, and profitability of these companies. Hence, adoption is quicker. Most of accidents are caused by human error. This could be reduced with Autonomous Vehicles leading to lesser vehicle damages and therefore lesser insurance claims.

Governments could lose revenue from traffic tickets raised for speed driving, drunken driving, red light jumping and other traffic offenses, as the vehicles are programmed to follow the traffic rules without any exceptions. There would be legal implications and governments have yet to come out with legislations. In case of accidents or deaths caused by Autonomous Vehicles, there are no clarity as to who is responsible – Is it the owner of the vehicle or the manufacturer of the vehicle?

Media consumption increases during the travel as the consumer is free of driving. This brings in more revenue to the telecom providers. The economic impact of autonomous vehicles is estimated to be $7 trillion in 2050 by Intel and Strategy Analytics in 2017 [26]. The automobile service and repair industry will be badly hit as the autonomous vehicles will greatly reduce accident repairs.

Conventional automobile manufacturers will see a new kind of competition from different type of business entering their domain, eg: Google, Uber, Apple etc entering this domain. Also, they will have to start building Electric Vehicles as these will be demanded in future.

5.5.3 Unmanned Air Vehicles

UAVs can be used for multiple purposes and has a very strong social and economic impact

5.5.2.1 Social Impact

There would be loss of jobs for delivery and postal people. This could increase the unemployment and have a negative impact on economy. One segment of the population benefitted by the drones would prosper, whereas the other segment could suffer. This would create an imbalance in societies.
Companies incorporating drones would prosper in which the benefit would go to the companies. Customers may receive their deliveries quickly. Delivery staff jobs will be impacted.

UAVs would be most desired in photography and videography. Some of its applications include home movies, sporting events, weddings, promotional videos for products /services, 360 panoramas, tourism aerial landmark, news, live event coverage, concerts , traffic reporting, aerial cinematography for movies, action/sports and documentary /expedition.

5.5.2.2 Economic Impact

The biggest economic impact of drones would come from the military applications. Projections by various consultancies and analysts range anywhere between from USD 20 to 127 billion by 2020 from the current USD 2 billion. While a significant share of this market is attributed to military or defence drones, the predictions also take into account the exponential (400-600%) increase in the consumer drone industry over the next five years due to technological advancements making drone flight manageable and their applications continue to grow across newer areas and sectors [27].

Military applications of drones include border patrol / detection, coastal surveillance and monitoring and enemy terrain mapping.

Healthcare applications of drones are in delivery of blood, organs and critical medical supplies in remote areas or in war zones etc.

Government agencies could use drones to provide data through aerial imagery and large-scale topographic surveys, which helps government officials prevent traffic jams, avert citizens from entering flooded areas, and design safer and more effective transportation infrastructure.

Some of the use cases include police surveillance, drug enforcement, forestry and fire protection, highway patrol and enforcement, bridge inspection, weather atmospheric studies and poaching for fisheries.

Logistics applications of drones includes delivery of items by eCommerce companies and government postal services. Amazon is already using this.

Agriculture sector applications includes pesticides spraying, irrigated land mapping, plant count, canopy cover, leaf area index, soil type, moisture, and classification. growth stage, plant height and health, yield monitoring, cattle herding, and spectral imaging

Utilities /Mining/ Oil/Gas sectors could use drones for the following:

- On- & offshore inspection of oil and gas platforms – sniffing of methane emission at well sites.
- Inspection of infrastructure like bridges, roads, railways, power lines & equipment, viaducts, subways, tunnels, level crossings, dams, reservoirs, retaining walls etc.
- Inspection of wind farm & power stations.
- Inspection of solar park & PV modules.
- Thermal energy efficiency inspections.
- Inspection of drilling rigs, pipelines & transmission network.

- Asset & utility inspection.
- Maintenance Surveys – Access areas that are not normally reachable.
- Radio Tower Inspections
- Hydro-line / Power-Line Inspection
- Wind Turbine Inspections
- Oil spill tracking
- Pipeline monitoring
- Hydrology & Geological Mapping

Disaster response use cases of drones include:

- Search and rescue
- Marine search and rescue
- Wildfire
- Flooding
- Damage Assessment
- Rapid response
- Surf lifesaving
- Fire detection

Real Estate use cases of drones include:

- Real estate / property photos and video
- Residential real estate marketing
- Commercial real estate marketing
- 360 Area shots

Environmental assessment use cases of drones include**:**

- Carbon capping
- Renewable energy
- Environmental Monitoring
- Waterway Monitoring
- Ice Flow Monitoring
- Parks
- Wildlife Conservation, Forestry mapping and Anti-Poaching
- Wildlife counts / Mapping of animal population
- Marine Biology
- Archaeological Site Mapping
- Tree & land cover mapping

5.6 Business Models

Business leaders should quickly re-define their business models to harness the advantages of ITS. Business Models of Automotive manufacturers will have to include innovative solutions to fully harness 5G capabilities like:

- Passenger infotainment requiring simultaneous high capacity and high mobility
- Cars with built-in driver assistance systems based on 3D imaging and built-in sensors.
- Vehicles should detect safety critical situations, such as accidents within reach of the car and other hazardous road conditions. Safety systems should also guide drivers on alternative courses of action to allow them to drive more safely and lower the risks of accidents.
- Augmented reality dashboards which overlay information on top of what a driver is seeing through the front window, identifying objects in the dark and telling the driver about the distances and movements of the object

Business Models of Automotive manufacturers should include partnership with Telecom Operators and Digital companies. Synergy between communications and transportation infrastructures is needed to support Connected and Automated Vehicles Telecom operators play a crucial role in providing the connectivity for connected car applications but lack the expertise to deliver specific services to vehicle owners. They need to partner with Automotive manufacturers.

The business model should also include partnership with digital companies like Google and Apple. Automobile companies which are going strong in this area are Tesla, Volkswagen, Daimler, BMW, Ford, GM, Hyundai etc. They do not have the expertise in application areas like Google and Apple. They would be benefitted by partnering with them. There is endless speculation about potential partnerships across the divide. Google partnered with Fiat Chrysler in 2015 to help develop connected car technology. Several carmakers are working with Apple and with Android to make Apple CarPlay and Android Auto – customised, in-car versions of the Apps Store and Google Play – to their customers.

The author has defined the 'Intelligent Transport Systems" Business model based on the Seven Dimensions of Business Model [36].

Value proposition –

- Cars with built-in driver assistance systems based on 3D imaging and built-in sensors.
- Passenger infotainment requiring simultaneous high capacity and high mobility
- Vehicles should detect safety critical situations, such as accidents within reach of the car and other hazardous road conditions. Safety systems should also guide drivers on alternative courses of action to allow them to drive more safely and lower the risks of accidents.

- Augmented reality dashboards which overlay information on top of what a driver is seeing through the front window, identifying objects in the dark and telling the driver about the distances and movements of the object
- Data derived from connected vehicles
- Predictive maintenance
- Connected navigation services
- Remote control of vehicles
- Driver's condition monitoring service
- Emergency call service
- Breakdown call service
- Surveillance through Drones
- E-commerce delivery through Drones
- Connected Vehicle Data.

Customers or Users –

- Owners of the vehicles
- Drivers/ Passengers of the vehicles
- Insurance companies
- Car sharing services
- Government agencies /Defence establishments.
- E-Commerce customers
- Third party marketers.

Value chain functions –

- 5G V2X connectivity from telco.
- Build fail safe autonomous vehicles
- AI/ ML based data analytics
- Drone operation
- Emergency services

Competences –

- Technology awareness in autonomous vehicles and drones.
- Data analytics
- Well trained emergency personnel

Network -

- Automobile Manufacturer
- Telecom Operators
- Digital companies

- Fleet operators
- Insurance companies
- UAV manufacturer
- Government agencies

Value formula

- Price of the vehicle with all features
- Content fees
- Infotainment fee
- Data monetization
- Subscription based fees for vehicle owners.

Relations – The integrated IT platform that links the automobile manufactures, fleet operators, telecom providers, digital companies, government agencies, emergency personnel, and vehicle users.

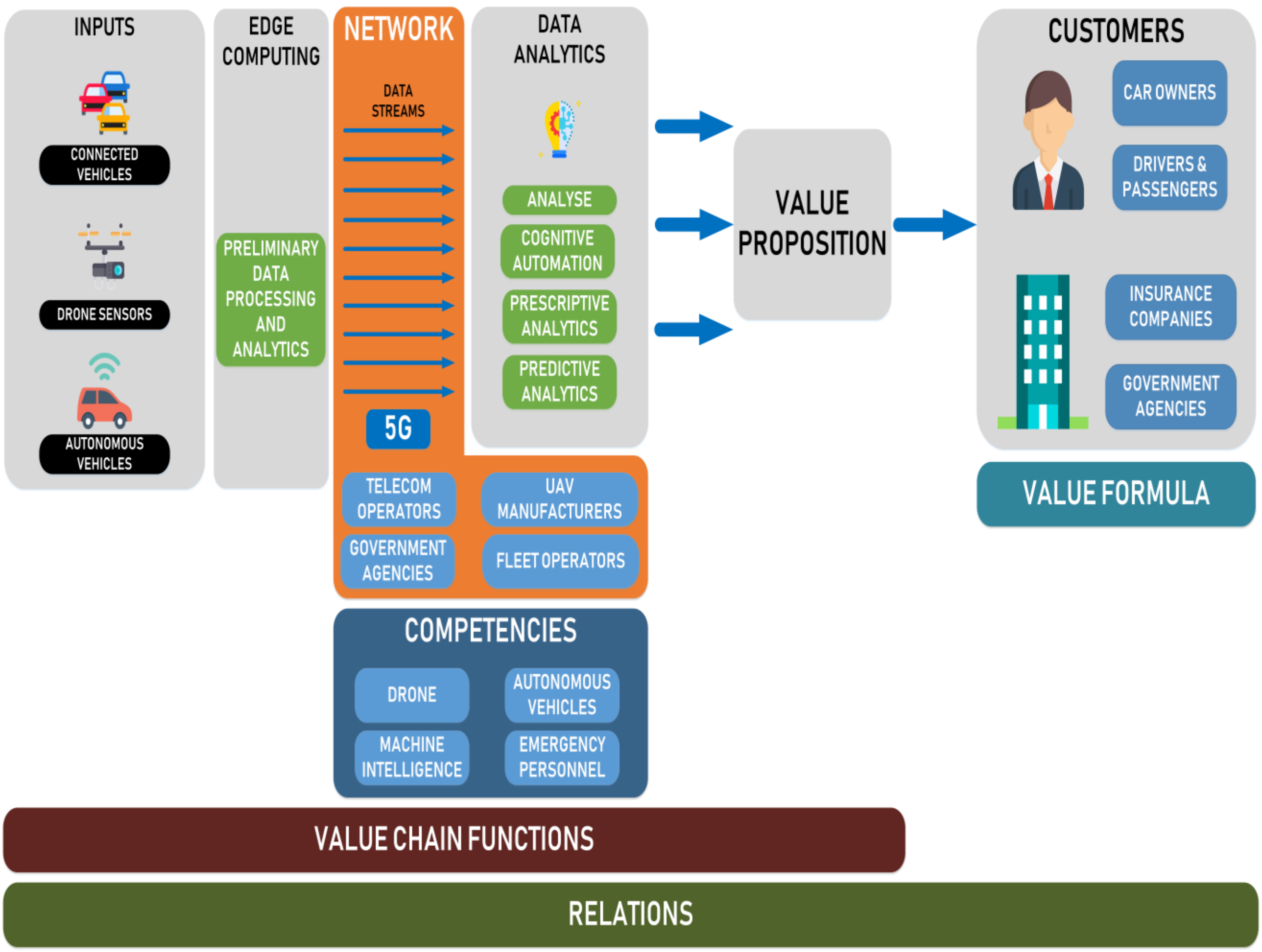

Figure 5.6: Intelligent Transport System Business Model

5.6.1 Creating Value from Connected Vehicle Data

Connected vehicles are equipped with hundreds of sensors, integrated with a great amount of smart technologies. Connected vehicles communicate with the driver, other vehicles, roadside infrastructure, and the cloud. They are collecting immense amounts of internal and surrounding data.

Sources of data in a connected vehicle are:

- Many Electrical Control Units (ECUs) which control the systems in an engine, door, suspension units etc. Each ECU controls several sensors that send data about something like a door opening/ closing, amount of oxygen in the engine cylinders etc. These kinds of sensors overseeing technical things in the different components of the vehicle produces huge amount of data every day.
- A second type of data (environment) that a vehicle generates comes from sensors picking up environment parameters, i.e. things that happen outside of the vehicle itself. This could e.g. be sensors deciding what the temperature and weather is like, cameras or radars generating data about pedestrians, other vehicles and other things around the vehicle, or data about the driver and the passengers. Connectivity with other vehicles also lets vehicles share data between one another.
- A third type of data can be fed to the vehicle through its connectivity to a cloud solution, meaning that data from third parties can be integrated with the data that the vehicle itself produces. Examples of third-party data that is fed to a vehicle are weather data, traffic data, or music.

Sensors can be installed anywhere easily but effective utilization of the data they produce could be a challenge as a certain pattern needs to be derived from the data. Digitalization and data bring with it, new business models and new opportunities to create value and generate revenues. Furthermore, gathering, storing, and processing data is associated with costs that companies need to weigh against the potential income it can bring. a process of value creation is needed, where data is made useful by processing and combining it in the right ways.

Vehicles extract data from their surroundings that tangentially improve the driver experience by acting as a real-world sensor that surrounding vehicles can leverage to determine real-time traffic and weather conditions. Also, vehicles communicating with each other can reduce potential crashes and improve traffic flows, all of which contribute to enhancing the driver experience. Data is valuable in elevating the driver experience. Vehicle manufactures can derive value from vehicle data because the vehicle is the source generating the data that other companies and third-party developers need to build new applications that ultimately impact the driver experience. Vehicle makers can monetize both the data stream by allowing access to specific streams of anonymized real-time data to third party developers, as well as the actual application like real-time traffic route guidance, through royalties charged to the third parties.

Some of the use cases enabled by vehicle data analytics which are valuable to Vehicle manufacturers and Vehicle users are:

- Usage-based insurance
- Usage-based tolling and tax
- Connected navigation services
- Remote control of vehicles
- Driver's condition monitoring service
- Emergency call service
- Breakdown call service
- Stolen vehicle tracking and theft protection
- Targeted advertisements and promotions
- Fleet Management services
- Remote vehicle performance configuration
- Vehicle usage monitoring and scoring

Apart from the vehicle manufacturers and owners, vehicle data could also find it use in the following:

- Vehicle data collected from all vehicles in a city, could be used by the traffic department to improve traffic systems and prevent traffic congestions.
- Weather and road condition survey throughout different regions.
- Disaster management and emergency service providers
- Third party vehicle ride sharing providers.

Each of the above use cases can create value either by generating revenue, reducing costs and enhancing safety & security. Users will be interested in features that makes driving safer and convenient and saves time and money. They could be averse to sharing of their personal data unless they see specific benefits to them.

5.6.1.1 Business Potential survey of Vehicle Data

Many research companies have estimated the business opportunity value from Connected Vehicle data. Harbor Research expects this value to be \$ 47 billion by 2023, out of which \$ 8.2 billion would be from basic systems software & services having applications like location, routine diagnostics and monitoring, the rest would be due to advanced value-added software and services having applications that include vehicle performance, contextualized in-vehicle experiences and V2X (vehicle-to-infrastructure, vehicle-to-vehicle, etc [28]. McKinsey & Company estimates the overall revenue pool from vehicle data monetization at a global scale to USD 450 - 750 billion by 2030 [29].

Prof Rothwell DN and Sir Mark Walport of Council for Science & Technology UK, estimates the Socio-economics benefits of Connected Vehicles to UK alone to be 50 Billion Pounds by 2030 to 900 billion pounds globally by 2025 and this market would include semi-autonomous, autonomous vehicles, communication and data systems [30]. Consultancy firm Frost & Sullivan (2017) predicts that as the automotive industry transitions from solely delivering products to increasingly delivering data-enabled services, more than one trillion USD can be added to the industry revenue pool by 2030 [31].

The above business opportunity can be realized only if vehicle manufacturers are able to build and test vehicle data driven products and develop new business models built on technological innovation, advanced capabilities and partnerships and more importantly be able to get public acceptance.

The conventional business models of vehicle manufacturers focussed on selling more vehicles. They need to change their business models from product-oriented strategy to a customer and service-oriented strategy. With new concepts of ridesharing, next-gen mobility, they should shift their business model focus away from physical vehicles to "custom design for individual" i.e. allow the customer to specify lot of convenience in the vehicle as per their preference. With personal context at the forefront, the driver and rider experience are becoming the true market differentiator. The business model should provide a seamless, personal, relevant experience to the user. The data to create this experience exists in abundance, and it is only growing more plentiful. The business models should enable the system to collect this data, leverage it to infer context, and create bold, revolutionary solutions. Inherently, hardware acts as a commodity, largely static and lacking dynamism. But using data to create a highly contextual, adaptable experience introduces a new paradigm: one where automobiles are no longer commodities but intimate, personal platforms.

The next generation of automobiles, empowered by data and applied in a highly personal context, will bring the soul of the individual to the forefront of a brand-new automotive experience.

5.6.1.2 Future vehicle manufacturers business models lie in data-driven experiences

Business models should address leveraging of data to drive more relationships and experiences between drivers and their vehicles for monetization. In a connected vehicle ecosystem, abundance of data will be created which can potentially provide insights into vehicle health and customer behaviour while the external ecosystem plays to the advantage of the OEMs in a pre-customer authorized way. Business models should include services such as predictive maintenance to predict future failure of vehicle parts and direct users to service centres before parts can malfunction.

Insurance companies can offer Usage Based Insurance analysing the driver's capability and usage patterns [32]. Location based services can be offered to drivers based on analysis of their personal preferences and behaviour data. Connected vehicle data can be used to increase internal efficiency, quality, and product differentiation for vehicle manufacturers. This data could be used to calibrate their own vehicles and redesign them according to the insights they got about vehicles performance. Data can be used to make smarter decisions about when to replace wear components in the vehicle instead of on regular service intervals. Further, data can help improve vehicle health through driving statistics, self-diagnosis, remote diagnosis, and real-time vehicle information. These are things that become even more important when moving to a business model where the OEM is the owner of the vehicle. Continuous monitoring and predictive analysis can enable maintenance even before a serious problem occurs. Vehicle recalls can be prevented, predicted, or minimised. In cases where problems are software related, possibilities for over-the-air software updates reduce the need for recalls as problems can be fixed without the need for recalling the vehicle at all.

The new business model for the vehicle manufacturer includes creating partnerships between Telcos, application providers and other 3rd parties. Such partnerships will become important in creating value for them outside their current value chain, where they will need to package data in ways that make it attractive [33]. Business models could include the costs of data monetization being bundled in the vehicle price or offering a subscription price. Different players to harness vehicle data monetization include vehicle manufacturers, telecom service providers, infrastructure providers, insurance companies, third party mobility aggregators etc. The traditional vehicle manufacturers, and their parts OEMs will find it challenging in adopting to this scenario. They need to make paradigm changes to monetize the full potential of vehicle data.

Let us look at how vehicle manufacturers are using vehicle data analytics. Tesla offered a package for new buyers which included cameras and sensors to warn drivers of collisions before it happened [34]. Tesla collected this data for a year and then offered the owners self-driving capabilities for their cars, through OTA updates. Tesla's advanced sensors and autopilot software have made it possible for them to collect lots of new data and to generate road maps for driverless vehicles, which includes information about e.g. where vehicles have slowed down for traffic and where vehicles have swerved around less visible obstacles that have appeared. The entire fleet of Tesla vehicles is educated by machine learning in the cloud, while edge computing in each individual vehicle lets it decide what action to take in each moment**.** Through unsupervised machine learning models, Tesla learned how to operate in traffic by simply observing human drivers. It is apparent that strategy of data collection and analytics, will drive development of autonomous vehicles [35].

5.7 Summary

5.7.1 Connected and Autonomous Vehicles

Connected car market has a long way to go. Firstly, assisted driving applications will become more commonplace so that the driver gets used to it. We know many of the building blocks of the connected car. We understand how it will be possible to gather information about the performance of the car (and the driver), the route that it is taking and the things that people are doing in the car. This data will be sent into the cloud, processed, filtered, and then fed back to the relevant parties (driver, passenger, dealer, automotive OEM, insurance company, fleet manager, rental company etc).

The development of the Autonomous Vehicles will take connectivity to the next level. We might soon have basic autonomous functions like overtaking, but fully automated driving will not happen until at least 2025. Before then, the industry has a lot of infrastructure to build. This means not just equipping highways with wireless technology but adding sensors to monitor pedestrians. Only when these things are in place, and in combination with intelligence inside the car and ultra-reliable connectivity provided by 5G, connected car will become a reality.

Telecom operators play a crucial role in providing the connectivity for connected car applications but lack the expertise to deliver specific services to vehicle owners. They need to partner with Automotive manufacturers. Synergy between communications and transportation infrastructures is needed to support Connected and Automated Vehicles.

Currently, the connectivity features are not integrated, and this will change with Automobile companies partnering with cloud technology and service providers. In future all the connected vehicles features will sit within an overall system and cloud-based architecture. Applications offered by the manufacturer and its partners will sit in the cloud and they will interact with each other, allowing them to offer new services to multiple customer types. For example, if the system detects a mechanical malfunction it will be possible to alert the driver, to notify the manufacturer (and its servicing department) and, for example, to offer an incentive to the driver to take his vehicle to get it repaired at a specific place and time. This is important because it demonstrates what can be achieved with a single operating system for a vehicle. They do not have the expertise in this and will have to build the skills to build and manage such an operating system or partner with companies like Google and Apple who have extensive experience in this. Once the partnerships are forged, clarity will emerge regarding who will own and manage the overall platform and what services and applications will emerge assuming that the platform will be open to third party developers.

Technical challenges for growth of ITS industry can be addressed with automobile, telecom and technology players coming together. However, the challenges for its success would be:

1. Lack of proper road infrastructure – Only few advanced countries have well defined roads and highway infrastructure which are very essential for the success of connected and autonomous vehicles. This technology would be not be successful otherwise.
2. Lack of standard traffic rules and regulation: Same as above. Most countries do not have proper traffic lights. Highways, rural areas and even suburbs in cities may not have traffic lights at all. Even if available, they may not be integrated into traffic management centre for analysis and control.
3. Governments will be unwilling to install communication infrastructure all along the all the roads and highways, as it is expensive and is not a social need.
4. Even good infrastructure may not help if all users of road do not follow proper traffic rules.
5. Also, defining the right of way in a road would be an issue. They can be programmed to understand ambulances, fire engines and police vehicles with sirens. But many countries have VIP cars (without sirens or strobes) with an indication of the number plate that it is a VIP car. This could be in the local language. This could pose a challenge.
6. Public will be very apprehensive of this, especially pedestrians and cyclists who are very vulnerable on the roads. Recently, a driverless car has killed a pedestrian.
7. Lack of regulations and standards. Many different departments are involved in this having their own agenda and policies, which will be challenging in developing an integrated policy.
8. Cyber security is a threat as the vehicles are networked and presents an opportunity to hack and physical steal or interfere with vehicles
9. Data Privacy -- GDPR is implemented in Europe to secure the personal integrity of EU citizens, who have to give clear consent to their personal data being collected and processed and be able to withdraw this consent at any time. Also, they have a right to be forgotten I,e their data should be completely erased and any further processing should be stopped . Adhering to these rules will be challenging to the vehicle manufacturers. They must design systems to anonymize data and yet be able to extract valuable insights from the data. Other countries like India are also bringing similar laws to safeguard data of their citizens.
10. Safety to people in the road – Public and other vehicle users on the road will feel threatened when they see a driverless vehicle alongside them. If anything goes wrong in the operation of the driverless vehicle, it can create havoc on the roads with probable loss of lives.
11. Safety to users of vehicles – The user sitting inside the driverless vehicle also faces above risks.
12. Ethical and legal issues – If a driverless vehicle is involved in an accident resulting to loss of life, the legal process of who is to be held responsible. Would it be the vehicle owner or the vehicle manufacturer?

5.7.2 UAVs

This is very promising as many of the challenges faced by the Connected and Autonomous vehicle industry are overcome. Countries are coming out with clear UAV policies, which describe the ownership, restricted and no-fly zones, usage, and applications. The applications enabled by UAVs are expanding to commercial, scientific, recreational, agricultural, and other applications such as policing, peacekeeping, surveillance, product deliveries, aerial photography etc. This opens huge opportunities in almost every domain. Governments would support this because it largely benefits them.

Here, the main requirement from public safety angle, is to ensure that it does not crash into public places. With the growth of enhanced connectivity and other technology, this can be avoided and regulation not allowing usage in densely populated cities can also help. Most of its applications are in defence, mining, agriculture etc with large areas of unpolluted lands and this may not be an issue.

5.7.3 Recommendations

- Vehicle manufactures should do extensive trials simulating actual road conditions, before bringing autonomous vehicles to mainstream roads. They should educate public about uses of this and allay their fears regarding safety. This responsibility lies with vehicle manufacturers.
- Regulators should allow driverless vehicles usage only after getting public mandate through a poll.
- If public is OK with the autonomous vehicles, Regulators should develop standards and regulations with respect data privacy and safety with respect to them.
- The policy environment would be complicated as it involves many different stakeholders from different perspectives. Policies need to be flexible to realize the benefits of ITS. Regulators should bring an integrated policy and legislation to address this. There are many policies addressing Public safety, Smart Cities, Transportation, Road Traffic, Air Traffic etc which address individual areas. As ITS has relevance in all of these, Regulators should bring an 'Integrated Intelligent Transport System' policy covering connected commuting, autonomous vehicles and UAVs, addressing public safety, vehicle to everything integration, security, flight restrictions, no-fly zones, emergency response etc. Convergence of transportation, communication and public safety policies are required.
- Government should bring out clear legal provisions on the accountability in case of accidents.
- Both businesses and governments should work together to get the best of benefits from connected vehicles.

The social issues and apprehensions could be addressed over a period and Intelligent Transport Systems, enabled by 5G, would have a great future.

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6.0 Socio-Economic Impact of 5G on Industries 4.0

6.1 Introduction

Industrial activity started many centuries ago with making of handmade goods. It progressed with the advent of machines powered by water and steam and further into mass production. Electronic automation further improved the manufacturing process. Now, it has gone beyond, into a stage of robotic assisted manufacturing, called as Industries 4.0, where manufacturing system elements are able to communicate, perform analytics to drive intelligent actions. This involves IoT, analytics, robotics, artificial intelligence, and augmented reality.

In this section, the author has traced the evolution of Industrial revolution and the technologies that have attributed to their progress. The author has listed some of the global trends in this domain and discussed the market drivers for this. The author has described the current limitation of communication technology in implementing Industries 4.0 and described how 5G technologies could be the technology enabler and further discussed the social and business impact of it. Finally, the author has discussed business models that could be followed in an Industries 4.0 scenario.

6.2 Industrial Evolution

Until many centuries ago, production of goods was made by hand and/or using some work animals. During the end of 18th century and beginning of 19th century, mechanical manufacturing systems which were water or steam powered, were used in manufacturing goods. This was the beginning of Industrial revolution and is known as **Industries 1.0.** This saw the dawn of organised employment sector where the owners of the industries employed people to work for them for a remuneration.

With the advent of electricity, manufacturing started using electric powered machines in the beginning of 20th century as it was more convenient than water & steam powered machines. Machines were designed with their own power sources which made them portable and easily transportable to be installed at the manufacturing premises. This is termed as **Industries 2.0.** This enabled mass production of goods by installing assembly lines and workers were trained on an aspect of manufacturing so that they do just that part repeatedly with perfection and speed. The objective was to increase the efficiency and effectiveness of manufacturing, so that more goods of acceptable quality could be produced at optimal labour cost.

There was an electronics revolution post 1970, and manufacturing systems were designed based on electronics devices like Integrated Circuits, to automate many tasks and further increase production volumes and improve quality. This is known as **Industries 3.0.** Here, individual machines were fully automated to assist workers. Software systems like material requirements planning, enterprise resource planning etc, were developed to further enhance production by bringing the ability to schedule and track process flows throughout the manufacturing life cycle. Here, the focus was on cost and quality control to remain competitive as businesses turned global. This phase of the industrial revolution saw some work being done by machines, wherever feasible. Rich countries started to move part of the production or the entire production to low-cost countries to reduce cost. This saw the advent of the formal supply chain management.

As technology progressed, Internet of Things has come into force currently which is a network of sensors, actuators, and intelligent controllers. This has enabled flow of reliable information between different elements, to enable further automation and convenience in mass manufacturing. This phase is termed as **Industries 4.0** which was originally conceived in Germany. This is developed by the integration of IoT and Cyber Physical Systems to the industrial automation domain to create factory and process automation so that products could be brought out faster to the market in a very efficient way [1]. Technologies like IoT, robotics, artificial intelligence, cognitive technologies, additive manufacturing, and augmented realities, facilitates Industries 4.0 towards the vision of the Smart Factory [2]. Here, the physical processes are monitored by cyber-physical systems which create a virtual copy of the physical world and make decentralized decisions. IoT helps in real-time communication of various elements of Industries 4.0 with each other and humans. Industrial revolution brought about advances in machines, networks and facilities which was augmented with the advances in ICT brought in by the Internet revolution.

The key objective of Industry 4.0 is to drive manufacturing forward: to be faster, more efficient, and customer-centric while pushing beyond automation and optimization to discover new business opportunities and models. By embedding modern technology into manufacturing, we essentially achieve Industry 4.0 objectives. Automation of single machines and processes was the key feature of Industries 3.0. Complete digitization and data integration into the value chain is the feature of Industries 4.0. Here, the objective is to connect machines, people, and physical assets into an integrated digital ecosystem that can seamlessly generate, analyse and communicate data, and can also take action based on that data without the need for human intervention[3].

Industries 4.0 will have

- Automated operation of the Industries with built-in or embedded computers, real-time monitoring, M2M interaction, and control.
- Huge amount of generated data being processed in real time which can result in instant decision making

- Globally interconnected value chains linking global suppliers, customers, business partners [4].

Industries 4.0 is about creating intelligent autonomous networks along the entire value chain by interconnecting machines, processes, and systems. Control will not be limited to one factory, but chain of factories spread globally can be interconnected. In addition, systems within the Industries 4.0 scenario are self-aware and provide complete insight into the factory, enabling faster decisions [5].

6.3 Global Trends

Human Machine Interface will be a steppingstone for Industries 4.0. Developments in Human Machine Interface programming software will increase market growth. In extreme harsh environments like Oil & Gas industry and others, it is exceedingly difficult for humans to operate and remote operations in such environments will be advantageous. The global Human Machine Interface market is expected to reach USD 6.31 billion by 2022 [6]. North America HMI market was the major market accounting to over 30% of global market in 2014. Asia Pacific is also fast picking up.

Industry 4.0 was identified by Germany as the future project to establish itself as a leader of integrated industry in its High-Tech Strategy 2020 Action Plan announced in 2013 [7]. In Germany, the investment in Industries 4.0 is growing steadily every year from 320 million euros in 2013 and is forecasted to be 2.02 billion euros in 2018. It is forecasted to increase to 2.62 billion euros in 2020 [8].

Globally, we see lot of investments happening to develop Industries 4.0. Countries which have invested, is realizing operational savings and decent digital revenues. Their plans for the next five years are even more ambitious and far-reaching, with digital products and services paving the way for disruptive business models. Globally, the investments in Industries 4.0 is expected around USD 907 billion per year through to 2020. Bulk of this investments will be on digital technologies like sensors, connectivity, and software. The expected return on investments is 2 years [9].

Countries having implementations of Industries 4.0 are Germany, US, Japan, China, France, Netherlands and S.Korea. In a survey by Statista among 559 industrial enterprises on their opinion on the leading nation in Industry 4.0 as of 2016, 28% of respondents stated that US was the leading country in Industry 4.0, while 25% felt that it was Germany and 20% felt that it was Japan [10].

India is keen in adopting Industry 4.0 and has taken several initiatives in Smart Manufacturing as part of its “Make in India’ programme. India’s first Smart factory is being setup at Bangalore and is developed at Indian Institute of Science with funding from Boeing, Sectors which have adopted Industries 4.0 in India include FMCG, Telecom and Healthcare [11].

PwC, in its global survey, has reported that globally there is an annual revenue increase of USD 493 billion for the next five years and USD 421 billion in cost reduction. Talent has been quoted as the challenge in implementing Industries 4.0 [9].

Statista, in its data security survey. has reported that about 10% of U.S. companies considered data security to be a big challenge regarding the implementation of Industry 4.0 [12].

'Made-in-China 2025' – the 10-year national plan announced by China in 2014 to transform itself into a world manufacturing power, included emerging new technologies leading to Industries 4.0 [13].

Prices of sensors, bandwidth and processing costs have dropped significantly in the last 10 years. Sensor prices have dropped to an average of 60 cents. Bandwidth cost has decreased by a factor of 40 times. Processing costs have declined almost 60 times [14].

According to ABI Research, the Industrial manufacturing applications will generate more than $ 138 million from mobile and satellite connectivity fees and Industrial IoT (IIoT). Connections will surge to 66 million global connections in 2017. Digitization of industrial processes has become possible due to the decreasing costs of data storage and compute processing. The largest growth of IIoT connections is happening in Asia Pacific region. The global connection is forecasted to grow by 18 million new IIoT connections annually by 2021. 25% of these connections will be wireless in 2017. This will significantly grow over the next few years [15].

According to MGI report, 75 million to 375 million workers amounting to 3% to 14% of global workforce will be impacted by 2030, due to automation and will have to switch their occupation. Also, there would be 50 million new technology jobs by 2030 which are required for development and deployment of technology [16].

Ubiquitous connectivity, cheap data rate, reduction in sensor price, reduced cloud commute and data storage cost, availability of massive data from operational technology, device sensors and enterprise systems, etc., are some of the key catalysts that are making Industrial IoT a reality.

6.4 Industries 4.0 - Demand Drivers

There is scarcity of workers in some developed and matured countries like Japan and US and this drives these countries to bring out manufacturing process which requires less human involvement. This is a driving force towards need for automation. Developing countries having large younger population are more tuned towards digitalization and adaptation to emerging technologies.

Cyber-Physical-Systems (CPS) is the basis of intelligently connected production systems that operate well beyond the physical boundaries of the factory premises. Industries 4.0 needs technical integration of the CPS in production and logistics as well as application of IoT in industrial processes. A wireless, broadband, global, reliable network with mobile support is required for operation of CPS in the factories of the future [4]. In the manufacturing environment, these CPS systems comprise smart machines, storage systems and production facilities capable of autonomously exchanging information, triggering actions and controlling each other independently.

The ICT requirements should facilitate on-demand manufacturing, which should satisfy customer demands and preferences and enable elasticity and flexibility in manufacturing [17]. The ICT requirements are as follows:

- New IT solutions and systems to be developed to integrate sensors, electronics, data acquisition and control systems, business, and other applications through efficient communication networks
- All machines and systems must be controlled and managed remotely from a central control system, through smart sensor and actuator technology, leading to IIoT.
- The system should have connectivity with its counterparts in any part of the world. Scalability should be available through Cloud Computing.
- Automation required, should be supported by Artificial Intelligence (AI), advanced robotics and sensor technology. AI should enable driverless vehicle inside the factory to do many tedious jobs and automate Supply Chain Management [18].
- System to provide for Just -in-time (JIT) manufacturing as required for customer's specific product configuration by having flexibility in inventory control and logistics.
- Industries 4.0 will be data intensive. Big Data and High-Performance Data Analytics should be performed to get good insights into the various process and take appropriate action in real-time.
- Virtual Reality (VR) and Augmented Reality (AR) solutions should be implemented to bridge the gap between virtual world and physical world and keep track of manufacturing processes and production.

Industries 4.0 needs a communication technology which must satisfy the industry specific needs w.r.t network infrastructure, timing, heterogeneity, safety and security. Timing requirements are specific to industry and production process. Typically, industries like food processing, are not very time critical and require cycle time of about 100mS. Automotive production and heavy machinery require typical cycle times of 10mS. Highest demand is set by motion control applications, like automatic guided vehicles and robots, which require latency of less than 1mS [4]. Communication technology should satisfy the requirement of latency less than 1mS.

Maintenance must be automated with a focus on optimally using material resources, manpower and energy. It should enable predictive maintenance to ensure that a machine is repaired when it is really required. Industries 4.0 should provide integration with global chains i.e Global Suppliers, Customers, and partners to provide a truly global value chain. Cloud based solutions enables data interchange between factories and across the whole global network. Smart logistics function of Industries 4.0 must integrate flexible logistics systems, new customer services, distribution method along with internal production processes through autonomous technologies. Also, it should provide high level of data security as data is now shared amongst various entities. It should offer flexibility in production re-configurations.

Exponentially growing technologies, listed below, will be main driver for Industries 4.0

- 3D Printing or Additive manufacturing
- Sensor technologies - High number of sensors and actuators are connected to the control units. This requires extremely high reliability
- Nano Technologies
- Artificial Intelligence
- Remote Robot control requires extremely high reliability
- Automated guided vehicles.
- Remote assistance provided through two-way augmented reality, requires very high reliability
- Augmented reality - Requires very high data rate of 10Gbps [19].
- Components tracking. Should be able to track at least a Million static devices per Sq Km [18].
- Devices in an assembly line communicates with the control system. Here the requirements is for extremely low latency of at least less than 1 mS and extremely high reliability [19].

From the above, we see that each of the use cases has specific requirements in terms of latency, data rates, reliability and density of connections, coverage area etc [19].

The above technologies have been for a while. However, with the advent of new Communication technologies, massive boost on computing power, cloud, and big data analytics etc have made them extremely useful for Industrial use. This exponential growth will be the driver for Industries 4.0 [18].
Some of the requirements of the Industry management are:

- How to increase top line by identifying customer needs and offering personalized products and services with faster turnaround and consistent quality?
- How to innovate with business model to generate new revenue streams?
- How to adopt sustainable business practices to contribute to the environment health and safety objectives, and increase brand value?
- How to embrace technology advancements and infuse them in the processes to achieve all the above?

6.5 Current limitations in implementing Industries 4.0

The essence of Industries 4.0 is in the connectivity amongst all the manufacturing elements enabling communication between them to share data for appropriate actions. So, it is required that all machines have standard interfaces to enable this communication. Lack of Standardization in Industries 4.0 has been a major challenge.

The various requirements Industries 4.0 as listed in the previous section, needs features like ultra-low latency, very-high reliability, very-high bandwidth, and data rates etc. These cannot be met by the current communication systems. Again, mission-critical connected systems cannot rely purely on unlicensed frequencies.

Wireless IoT markets are limited in potential with 3G/4G (LTE) networks, since limitations are experienced in:

- Backhaul/fronthaul connections are mostly wired and indeed costly for ad hoc deployment (Wireless backhaul/fronthaul faces capacity and reliability limitations in 3G/4G)
- Reliability of wireless connection is not enough for mission critical applications. Target reliability should be > 99.999 %
- Energy consumption of devices due to today's communication networks, is too large to meet battery life duration targets
- End-to-End delay is too long and not predictable for remote control and actuation. Latency of less than 1mS is not possible.
- Delocalized computing is starting to be introduced but requires high uplink bandwidth that 3G/4G systems cannot ensure
- Extreme density of IoT devices is not supported
- Communication overhead of low rate IoT communication breaks optimized functioning of 3G/4G networks

6.6 5G – Industries 4.0 Technology Enabler

The communication needs of Industries 4.0 are very stringent with requirements of very high data rates, very high reliability, and ultra-low latency. We have seen, in the earlier section, the limitation of the current communication technologies in addressing these requirements. These requirements are supported by the advanced features of 5G like 10Gb/s data rates, latency of < 1mS, 10 to 100 times faster and having greater capacity than 4G LTE, support of several billions of applications and hundreds of billions of machines with improved device battery life, always-on user experience, network slicing and reliability up to 99.999%.

5G will enhance connectivity access to industries and enable new applications and use cases. Typically, Industries had to depend on slow and expensive deployment of fixed ethernet networks for connectivity. 5G enables wireless connectivity offering higher speeds and bandwidths. This will enable faster and flexible deployment of machines and other devices in the industry without the need to install cables. Traditionally, industrial operational technology networks are completely wired because of zero tolerance, when it comes to network reliability and latency. There is no suitable wireless alternative. The field sensor devices are connected to the industrial gateway, distributed control system (DCS) and supervisory control and data acquisition (SCADA) systems through wired networks using the Ethernet.
5G will enable new applications by enabling higher device density resulting in increase of data volumes, ultra-reliability, and low latency. The increased data volumes can help the factory personnel to get a deeper view of the status of the machines and systems and thus be able to identify problems accurately. The ultra-reliability feature ensures that the data controlling the processes, are accurate and dependable. The low-latency feature can enable real-time response to stimulus, ensuring that mission critical applications can function satisfactorily.
5G has the potential to provide a powerful connectivity between people, machines, and objects, which is the essence of Industries 4.0. This can give rise to diverse use cases and applications in the industry. 5G-ACIA forum, which is a joint venture between well-known industries, considers 5G as essential in the development of Industries 4.0 and are working towards brining standardization of the industry requirements on 5G [20].

5G will accelerate Industries 4.0 in the following ways:

- **Massive Industrial IoT mMTC -**

The massive IIOT supports deep coverage and density inside the manufacturing plant and supports remote sensor monitoring. Manufacturing industry will be large adopter of IoT. Huge amount of data and information are generated from these connected devices which will need 5G's capacity and speeds. Industries 4.0 is constituted with billions of sensors, actuators, robots, automated guided vehicles etc, all communicating in real-time with each other and with central control system. This is enabled by the ultra-low latency combined with MTC features of 5G resulting in the entire operations being automated and being able to be remotely managed and controlled in real-time [4].

- eMBB feature of 5G supports faster and more reliable mobile broadband than 4G, offering richer VR, AR and cloud-based services.
- Ultra-reliable and low latency (URLLC) communications (uRLLC) - The mission critical communication features of 5G like ultra-reliability and low latency, supports motion control applications, robot

control and application monitoring resulting in process automation and remote control of machines in hazardous conditions.

5G will be key to supporting the wireless connectivity needed to power Industries 4.0 through its massive Machine Type Communication (MTC) feature which can enable real -time control of machines, robot/ human interactions, and edge cloud analytics. 5G technologies plays a key enabling role in integrating technologies like IoT, Cloud, Big data, Security etc which are the components of Industries 4.0 and offering a unifying platform to interconnect machines, robots, processes, auto guided vehicles, goods, remote workers, etc. With 5G connectivity, all manufacturing systems can communicate with each other feeding back office or control systems with continuous real-time updates. Industrial services have different requirements in terms of speed, coverage, latency, and reliability, which will demand different network solutions and deployment models, appropriate network infrastructure (wired & wireless) and different spectrum bands.

- **Robots**

5G utilizing edge computing capabilities, can help to enhance the capabilities of robotics with its high speeds, larger bandwidth. Auto manufacturing is using co-bots, or collaborative robots, to complete hard to reach, dangerous tasks underneath the car while human workers perform tasks outside the car. 5G will eventually help these robots become more agile, making faster decisions, and quickly adjusting to changes in near real time. Such type of smaller autonomous and collaborative robots on the factory floor can perform a variety of tasks which may not be able for workers to do. These robots will not only help take the load off their human co-workers but will ultimately help factories optimize production. So, the workers can operate dangerous and heavy machinery, at a distance which helps to ensure safety of the workers. It will also enable people and robots to work together.

- **Network slicing**

5G enables flexibility in networking through 'network slicing'. A single physical network can be separated into multiple virtual networks through network slicing. Each 'slice' can be customised with further virtual private networks to meet the needs of specific applications, services, and devices. When used in combination, 'slicing' and virtual private network technology could enable a machine tool provider to allow customers and other suppliers, such as automation or metrology providers, access to their 'slice' via an app. This would provide a secure area in which information can be stored, shared, and analysed. However, most importantly, each virtual network or 'slice' will be isolated. As such, if cyber-security is breached in one 'slice', the attack is contained and cannot spread. This in turn will generate a level of confidence amongst manufacturers. These capabilities coupled with network function virtualization

(NFV) and Software Defined Networking (SDN) can help manufacturers to optimize their network for ideal performance [21].

➢ **Augmented Reality & Virtual Reality**

Large bandwidth is needed to run AR & VR as workers must be physically connected to the network to use these technologies. Higher bandwidth of 5G will enable workers to use these anywhere in the factory floor as connections would be more stable. They will be able to use this for machine maintenance, data visualization, designing and training. All workers having AR headset can visualize machine maintenance instructions in real-time and take corrective actions.

5G's objective of integrating networking, computing, and storage resources into one programmable infrastructure, creates an optimal and dynamic application of all distributed resources.

➢ **Artificial Intelligence & Machine Learning**

Industries 4.0 needs AI to control factory floor production with little or no human intervention. It will also be used to predict issues in the supply chain, prevent fraud and assess production opportunities.

AI needs access to large amounts of near real-time, quality data to work efficiently. 5G's massive IoT connections and fast speeds, combined with edge computing power, will enable AI to quickly "learn" and make smarter, faster and more reliable decisions [22].

Industries 4.0 Use Cases need ultra-low latency, very high reliability and very high data rates cannot be supported by the existing communications technologies and need a new technology. This is where 5G come into picture.

5G will have a "massive impact" on industry and mobility, its usage will go beyond the application of consumer mobile broadband. 5G will allow manufacturers to automate end-to-end operations and setup or take down new product lines or entire factories virtually. With billions of sensors, machine-controlled robots and autonomous logistics, all capable of communicating and operating remotely in real-time via 5G, manufacturers can achieve massive productivity gains. 5G will be the platform enabling growth and transformation in many industries, directly contributing to social and economic development [4]

Ultra-low latency, combined with MTC and Intelligent analytics, will make it easier for people and robots to work collaboratively. It will also enable control of machines in real time. This means the workforce can move more freely, away from heavy machinery which helps to increase safety. And with massive

connectivity, all the machines can interact with each other, providing continuous updates to back-office systems.
With massive Machine Type Communications (MTC), real -time control of machines, robot/ human interactions and edge cloud analytics, 5G will be key to supporting the wireless connectivity needed to power these new “Smart Factories”
IoT technology, cloud solutions, big data crunchers, and cyber security components are key ingredients for this digitalization. 5G technologies can play a key enabling role in integrating these technologies and offering a unifying platform to interconnect machines, robots, processes, auto guided vehicles, goods, remote workers, etc. By integrating these technologies in a manageable way and extracting data for taking actions, efficiency and flexibility of the system are enhanced.

5G technologies will be the key in supporting all communication scenarios and offers mobility-features and seamless service experience. This role of 5G technologies very well corresponds with the 5G objective to integrate networking, computing, and storage resources into one programmable and unified infrastructure. This unification will allow for an optimized and more dynamic usage of all distributed resources, and the convergence of fixed, mobile and broadcast services.

The envisioned 5G platform will need to link wireless access with wired industrial ethernet and will also include components like edge computing, cloud, local gateways, big data and analytics, IoT management, etc. Furthermore, the boundary between wide-, local- and personal-area networks is getting more blurred, calling for a seamless interaction between those domains [4].

Automation is the key for Industries 4.0 and can be classified under [23]:

- Factory Automation which is the automation of operations in the production of goods which can be vehicles, home appliances, electronics products etc.
- Process control automation in which the processes are automatically controlled based on continuous data acquisition and analysis. Process industries include oil refineries, power plants, paper mills etc.

There could be many use cases in the Industries 4.0 based on above automation scenarios. These Use cases will have their own specific requirements in terms of data rates, latency, reliability, number of connections supported, field coverage etc.

Some of the typical Use cases are listed below [19]:

- Cell Automation - Devices in an assembly line communicates with the control system. Here the requirements are for very low latency of at least less than 1 mS and extremely high reliability

- Automated Guided Vehicles to move around in the factory carrying products to different stages as programmed. This requires mobility and very high reliability

- Process Automation – Large number of sensors and actuators are connected to the control units. This requires very high reliability

- Logistics transportation tracking of goods throughout the supply chain ie from raw material to shipped goods - Should be able to track at least 100000 devices per Sq Km and should have global coverage.

- Components tracking- Should be able to track at least a Million static devices per Sq Km

- Remote assistance provided through two-way augmented reality requires very high reliability

- Augmented reality - Requires very high data rate of 10Gbps

- Remote Robot control requires very high reliability

From the above, we see that each of the use cases has specific requirements in terms of latency, data rates, reliability and density of connections, coverage area etc

5G's objective of integrating networking, computing and storage resources into one programmable infrastructure, creates an optimal and dynamic application of all distributed resources. The 5G smart factory of the future will centre on a fully connected experience. From massive device connectivity and innovative technology experiences to near real-time automation and network flexibility, 5G will help bring major advancements to the smart factory. And manufacturing companies could ultimately realize major benefits such as performance improvements, operational efficiencies, and increased safety.

6.7 Socio-economic Impact

6.7.1 Social Impact

'The future of jobs report 2018' of the World Economic Forum [24] states that ubiquitous high-speed mobile internet, artificial intelligence, big data analytics, and cloud technology are the main drivers of global change. The report further states that by the year 2022, these drivers for change will result in an accelerated technology adoption by around 85%, including a robotic adoption around 23% to 37% and supply chain changes by 59%. It is expected that by 2022, there will be an increase in shifting of specific tasks performed by machines or algorithms increasing by 57%. By 2022, even the work tasks being exclusively performed by humans like communicating, interacting, coordinating, managing, decision making etc, will get automated by around 9%. There will be a 10% decline in existing jobs and a 11% growth in new jobs globally. The above changes will result in a job disruption leading to a large-scale redundancy of existing jobs along with a large-scale growth of new jobs requiring entirely new set of skills like AI, machine learning, big data, robotic process automation, security, blockchain etc. It is expected that there will be an average shift of 42% globally in required workforce skills over the period of 2018-2022. The top emerging skills include Data analysts, Data scientists. AI/ ML specialists, Software applications developers, Digital transformation specialists. The top declining jobs include Assembly & factory workers, Data entry clerks, Stock keeping clerks, Bookkeeping clerks. Skills around analytical thinking, innovation, creativity, critical thinking, emotional intelligence, will be sought after.

McKinsey research during 2017 across 46 countries comprising around 90% of global GDP and 800 occupations, suggested that automation technologies including AI and robotics has the potential to disrupt job market by causing decline in some occupations and creating new occupations that do not currently exist. By 2030, the extent of the work potentially displaced by adoption of automation could range from 0% to 30%. This means that some 800 million jobs have the potential to be displaced by 2030. Workforce that could need to change occupational category would range from 0% to 14% and could be around 375 million workers. Developed countries would be adopting automation at a higher rate than developing countries for economic incentives. Also, there would be 50 million new technology jobs by 2030 which are required for development and deployment of technology. However, there will be increase of job requirement in other areas like healthcare, infrastructure, and energy. Healthcare itself have up to 130 million new jobs fuelled by aging and rising incomes by 2030. Infrastructure could see between 80 million to 200 million new jobs and Energy sector could see up to 10 million new jobs fuelled by investments in renewable energy, energy efficiency and climate adaptation. There would be increase in new jobs in services like childcare, domestic help etc [25].

Disruption is defined as a break or interruption in the normal course or continuation of some activity, process etc. A job loss is one where one loses a job due to some event at the organisation like the company facing financial hardships, loss in business. merger/ acquisition etc. The person can find similar work elsewhere with the same skills he/ she has. More serious than a job loss is a job disruption or career disruption, where the type of the job the person is doing, itself disappears. So, the person would be unable to find the type of the job being done till then for the skills the person possesses. One of the reasons that this could happen is when there is a paradigm shift in the technology making some type of jobs totally redundant. The job disruption represent two parallel fronts of change in workforce transformations --Large-scale decline in some roles as tasks within these roles become automated or redundant, and large-scale growth in new products/services—and associated new tasks and jobs—generated by the adoption of new technologies and other socio-economic developments such as the rise of middle classes in emerging economies and demographic shifts.

Industries 4.0 supported by 5G will bring in high technological change in automation, as described in earlier sections. This would disrupt the Industrial job market by displacing certain kinds of manual jobs and bringing in new types of jobs required for automation. This would enable new opportunities in Industries by creating employment due to its own network infrastructure implementation and because of the new applications being enabled by it. Implementation of Industries 4.0 needs new special knowledge and skills, which will impact the supply of manufactured goods. It is imperative to develop creative human resources who are innovative and adaptable to changes of technology. This could make many existing job functions irrelevant and reductant, especially those which are repetitive and non-intelligent tasks, which tends to get automated. There would be demand for highly qualified automation personnel, whereas middle level and low-level jobs would take a hit. Jobs involving routine, repeatable work like production, office support etc would decrease. i.e. job functions which are capable of being automated, would be reduced. Jobs involving knowledge like implementing automation, technical roles, research and innovation areas would increase [26].

Certain case of industries like oil & gas industries etc, are very much benefitted by introduction of automation and robotics as they are too dangerous for humans to work in such environment. This helps in reducing stress of the workers, prevents health hazards and could save lives.

There will be intense competition for talented and skilled professionals and the industries could find scarcity in this. This would give rise to income disparity in society, as there could be mass job cuts and fewer new jobs with very high pay due to the skills shortage. Educated and skilled in newer digital technologies would get an edge in salaries and this would intensify the income gap. It provides ample opportunities for new kind of digital skills. So, it is important for Industrial workers to up-skill and re-skill. It will be required to continuously upgrade their skills as technology keeps changing.

Industries 4.0 can widen the gap between developed and developing countries. Developed countries like US, UK, Japan, Europe etc have been subcontracting high volume manufacturing work to developing and poorer countries for cost arbitration as the wages would be much lower in those countries. These countries were benefitted as it provided employment and means of livelihood to their large population. The developed and advanced countries are characterized by ageing population and lower workforce [23]. Industries 4.0 could automate manufacturing so that the need to subcontract does not arise. They could mass produce high quality goods faster with less workforce in their own country. Also, they will be able to flood the global market with cheaper goods. So, subcontracting work to low-cost countries may reduce. The rich and developed countries who can afford 5G enabled Industries 4.0, can greatly benefit with new opportunities. Developing and densely populated countries who have abundant of manual labour could become victims of Industries 4.0 and will have large scale unemployment leading to social unrest there. Large scale job disruption is expected in a country like India. Around 70% of jobs there could become irrelevant due to AI, according to Telecom Secretary, Govt of India who hold the highest office in Digital communication policies in India [27].

Author concludes that technological innovation could lead to certain types of manufacturing and service jobs to be displaced but bring in the requirement of new job skills. Growth of labour-intensive manufacturing industries will not happen in developed countries, as such countries would embrace technologies faster. Government policy makers and business leaders should embrace the new technology benefits as they could create more efficient and productive business giving rise to higher economic benefits and newer jobs. However, they should address the transition of the workforce caused by the changes. They should provide job retraining and upskilling for workforce to work on new types of jobs, maintain robust economic growth to support job creation and provide income and transition support to workers. People also must pro-actively adopt continual learning and re-inventing themselves to remain relevant in the job market. People must become lifelong learners.
Universities will have to update their syllabus to ensure that they produce people who are immediately employable after their studies. They must foresee the near future and the skill requirements in the industry and should be in synch with that on the go. They should have a panel of industrial experts and practitioners who can advise them on this and get such experts to teach special futuristic topics until their own teachers could learn that.

6.7.2 Economic Impact

While Industry 3.0 brought about automation in the industries, Industries 4.0 will bring intelligent connectivity through the power of 5G. Industries 4.0 enables workers, machines, sensors and devices to connect and communicate with each other, providing new opportunities and enhancing productivity and efficiency in manufacturing, thereby creating smart factories. The cyber physical systems monitor physical processes creating a virtual copy of the physical world and communicate with each other in real-time over the Internet of Things, to make decentralized decisions. This is further collaborated with the use of Artificial Intelligence, which helps in learning the entire process and the predictive maintenance requirements, thereby improving the resource efficiency and productivity.

The impact can be classified under three broad categories:

- Precision monitoring, control and Automation
- Predictive Maintenance
- Augmented Reality

Precision Monitoring, Control and Automation

- 5G enables massive machine type communication. Machines that can communicate intelligently with each other, can perform simple task leading to automation. Automation is the key for Industries 4.0 and can be applied both for product manufacturing and process industries [23].
- The cyber physical systems enable seamless and instant data sharing which can support decision making and problem solving.
- Systems can become autonomous and able to make decisions on their own in real-time.
- The operations in the production of goods which can be vehicles, home appliances, electronics products etc. in a manufacturing plant can be fully automated.
- Increased technological integration and predictive analytics increases efficiency and thereby helps to save costs.
- Companies can offer more customized products which will be profitable and helps to expand business.
- Manufacturing of a product in high volume has many substages and requires the parts being assembled to be transferred or transported to subsequent stages. This used to be a very labour and time-consuming task, which now can be done by Automated Guided Vehicles carrying these parts and moving around the shop floor to deliver or pickup at other stages. The mobility ad high reliability feature of 5G supports this.
- Supply chain management will become global and businesses will become competitive, enabled by logistics transportation tracking of goods throughout the supply chain. The scalability, extended coverage feature of 5G supports this.
- The operations in process industries, like oil refineries, power plants, paper mills etc, can be fully automated based on continuous data acquisition and analysis.
- Mobile Edge Computing enables computation to be done at the device in real-time for critical operations. Automated intelligent decisions can be made with help of AI, removing human errors. Machine learning models enrich the intelligence embedded in the process logic to make better decisions that align with the objectives of the industries over time.
- Other application 5G is going to enable is, edge cloud computing from within the communications network. This multi-edge cloud can bring lower round-trip latency and higher overall availability. All these characteristics of 5G are going to bring massive value to manufacturers in equipment availability, product quality, and safe and sustainable manufacturing operations.
- With the advancement in sensor technologies, it is possible to make the product smart. With smart products, manufacturers can gain real-time insights of their products and usage pattern. Data generated in the field can be used to improve the product design and performance. It can

also help reduce the churn rate of customers by offering superior customer service around smart products. With smart products, businesses can innovate with their model by offering product as service or creating new offerings and monetizing them.

Predictive Maintenance

Energy leaks, caused due to faulty equipment, can add to additional operational costs. In the conventional preventive maintenance approach, such equipment is sent for repair or replaced with backups and this causes stoppage of production and subsequent loss. It is important to predict a failure of a machine or a system before that event happens, so that corrective measures can be taken much in advance. This can ensure smooth running of operations and reduce energy leaks.

- Industries 4.0 enables continuous monitoring of equipment. Sensors in the equipment will indicate about the health of the equipment when they need to be serviced. Analytical models can be applied to predict problem areas and preventive action can be taken in advance. Predictive maintenance can reduce maintenance costs of factory equipment and bring down their downtime considerably.
- Predictive maintenance provides real-time advance failure detection alerts by monitoring the energy consumption patterns of devices/machines and benchmark them against similar devices/machines and locations. Unexpected failures of devices or machines are thereby avoided. For e.g., when a machine begins to draw unusually more power, it could be attributed to some part in the machine causing this increased power consumption. This can lead to a prediction that the part is likely to fail, so that corrective action could be taken before the production comes to halt. This can reduce energy waste by identifying in efficiencies in real time. Behnoush Darabnia and Micaela Demichea had developed a model to determine the energy efficiency improvements using predictive analysis. This model helped in decision making for maximization of energy efficiency through predictive maintenance. ***Results demonstrated that it was possible to increase the performance of the system up to 10% through predictive maintenance*** [28].
- Power costs form significant portion of the operation costs. Power consumed in a factory can be measured using sensors in the factory and each of the equipment. Based on the Time of Day tariffs and the energy consumption patterns of each equipment, production can be scheduled to consume optimal power without sacrificing the customer commitments. This will reduce the power costs.
- Typically, machines and equipment in an industry will have limited number of measurements points due to limitations in sensor connectivity and associated lower speed of data acquisition. 5G will support predictive maintenance by enabling connectivity to large number of sensors which will allow real-time reliable measurements of dozens of different parameters like temperature, pressure, humidity, vibrations etc. Prediction of failures can be made from analysing the real-time data gathered against historical data and trends. Proactive maintenance can be made based on the prediction of failures, thereby ensuring that systems are set right before they can fail otherwise.

Increase in device density, ultra-reliability and low latency enabled by 5G connectivity, ensures that large data volumes are made available for accurate prediction. This reduces downtime which is a critical factor in the successful operation of industries. This also reduces the cost on maintenance as the maintenance will be proactive and reduces the replacement rates of equipment.

- 5G enables large amount of data acquisition in real-time. Predictive analytics applied on these data can help pre-empt the equipment condition and reduce the unplanned downtime and production loss. It can also help produce consistent quality of product by providing early indicators of product defect to reduce rejections, rework, and warranty claims.
- With better visibility into the plant availability and control on product quality, manufacturers can achieve better on-time and in-full delivery performance and achieve higher revenue.
- With IIoT, manufacturers can monitor energy consumption in real-time and find opportunities for savings, as the energy cost contributes to significant portion of manufacturing cost.
- The largest energy consumers in a manufacturing plant are the production line and the building facilities like heating, ventilation, and air conditioning (HVAC) system. Industries objective is to reduce overhead costs, maintaining quality and efficiency of operations. Enhancing system wide energy efficiency helps in reduction of overhead costs. Overheads due to power consumption in a manufacturing industry can be remarkably high. Around 85% of the total power consumption in a manufacturing industry is directly not related to the actual production of the product. Industries waste many energy savings opportunities through the lack of integration between the facility and the production system. The concept of energy opportunity window can be utilized for each machine to turn machines off at set periods of time without any throughput loss. The recovery time of each machine is explored analytically. This provides the minimum amount of time a machine must be operational between opportunity windows to guarantee no production loss. The opportunity window for the production line is synced with the peak periods of energy demand for the HVAC system to create a heuristic rule to optimize the energy cost savings. Mckinsey reports that the potential energy savings that arises from improving the energy efficiency in manufacturing in US alone, could be around $ 47 Billion per year[29].
- Predictive maintenance, where real-time data generated from the IIoT systems, can be used to predict defects in machinery. It can ensure that action can be taken before the machine breaks down, by monitoring machine performance like vibrations, temperature and other factors. This is to ensure that the performance of the machine, and hence, the quality of products, is optimal. Other areas include, remote inspection and diagnostics, tracking products and machine inventory, using AR/VR for maintenance and training, management of production facilities, the use of robotics on the shop floor, tracking goods post-production, etc.
- Automobile engine manufacturers test every engine that they have assembled, first using cold test bed, and then using hot and load test bed. These tests contribute to approximately 1% of the overall

engine cost. Moreover, hot and load test significantly increases the cycle time and introduces the bottleneck in the production operation. With predictive analytics, it is now possible to analyse huge amount of data generated from test bed equipment and engine test cycle across historical tests, to predict whether the engine is be required to be sent to hot test or load test, reduce the cost of engine testing and reduce cycle time. Edge computing will enable faster processing of data at the edge to speed up decision making.

The energy management benefits realized through 5G enabled IoT and Predictive analytics are:

- **Asset efficiency analysis**: Real-time collection and analysis of varied data helps in calculating asset efficiency. Moreover, it helps determine cost implications of non-optimal performance of devices. Asset efficiency can decline due to maintenance issues or age factor. Techniques like benchmarking help in computing the optimal efficiency levels of devices under specific environmental conditions. This data can be used to identify situations wherein excessive energy is being consumed. This can be used to calculate the cost implication of maintaining energy devices with the help of predictive analytics.
- **Root cause analysis** can be done when the energy consumption level is higher than the expected levels. IoT enabled data can be used to validate the hypothesis generated from root cause analysis.
- **Warranty Lifetime Analysis**: Predictive analytics helps in determining the optimal warranty period and cost of the equipment/device. If it is observed that some devices fail at the early stages of the lifecycle, a longer warranty period can be availed to cover these failures. The device may not fail totally but some components may be prone to failure. In addition, warranty analysis becomes prominent in the case of error-prone components of an expensive device.
- **Predictive analytics** can help in identification of areas requiring power correction to reduce energy costs. Accurate analysis of alarms, exceptions or manual overrides brings forward the discrepancies registered during operations at regular intervals. The optimal state, possible reasons of deviation, and preventive action for running automated operations, can be determined.

Augmented Reality

- Virtual reality and Augmented reality bridge the gap between virtual world and physical world to keep track of manufacturing processes and production. With simulation models, they can improve the entire manufacturing chain, as manufacturing personnel with head mounted displays can see all the important data with their eyes through the display, with their hands free to do some other job. Simulations can be used extensively in manufacturing operations to mirror physical world of machines, products, and humans, in a virtual model to test and optimize machine operations before actual production.

There could be many use case scenarios in Industries 4.0 having their own specific requirements in terms of data rates, latency, reliability, number of connections supported, field coverage etc [19]. Some of these use cases are time-critical while others are not. Industries 4.0, enabled by the ultra-low latency and very high reliability features of 5G, supports efficient production lines with real-time monitoring of the performance and quality of finished goods. Use cases based on vision-controlled robots would need low latency and high bandwidth communication and is enabled by 5G. There are many scenarios where time is not critical as compared to the machine control. These includes packaging & shipping of goods, monitoring of certain assets, routine collection of data for historical analysis. However, high availability would be required for coverage in harsh environments, indoor locations. These use cases are supported by the diverse features of 5G.

The introduction of IoT and adoption of Industrial Internet in Industries 4.0 could present new type of security threats and vulnerabilities, as there would be lot of information flow throughout the manufacturing life cycle right from product concepts, design, development, testing, manufacturing, supply chain to maintenance. The business must evaluate these new risks and take adequate protection measures. According to STL Partners report, impact of 5G on Manufacturing is $ 740 Billion of benefits in 2030 [30]. According to Grand View research. IIoT market size is $949.42 Billion by 2025with a CAGR of 29.4%/ [31].

5G enables remote control of factories.

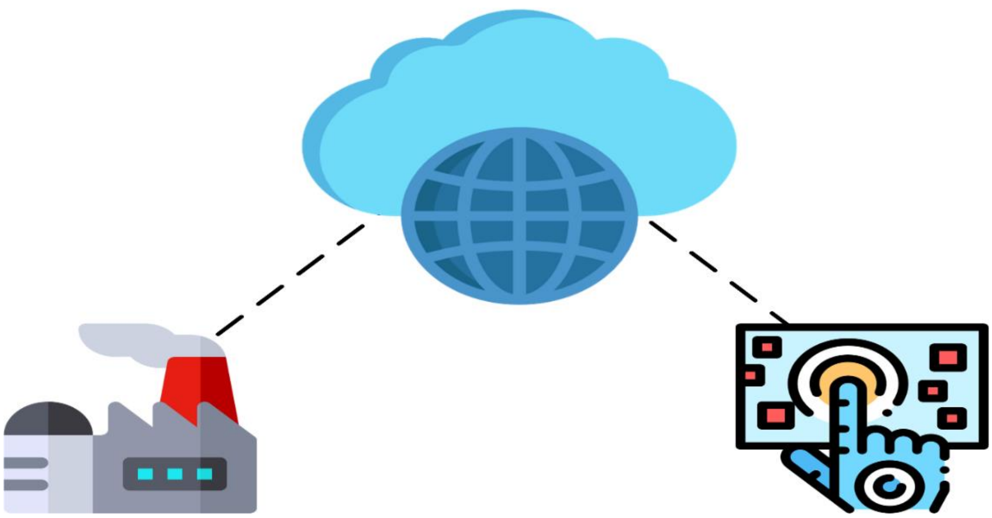

Figure 6.1: Remote control of factory

Workers could access and control the operations of the factory from a remote location through their mobile device or a central operation control room as shown in **Figure 6.1.** This provides remote control through augmented reality devices which ensures precise remote-control assembly and facilitates remote machine repair and maintenance. Here, the requirement is for high availability and high bandwidth network with low latency and high security which are supported by 5G.

Businesses nowadays operates in multiple locations within its own country and outside the country. They can retain their core product conceptualization and design in-house and may outsource other functions like product manufacturing, testing and logistics to other low cost or specialized countries. They could source components and raw materials from the most competitive source globally. They could manufacture in one country and sell globally.

The network and service availability and reliability offered by 5G will ensure connectivity amongst all these locations for seamless real-time operations, as shown in **Figure 6.2**. This will also allow monitoring of distributed assets.

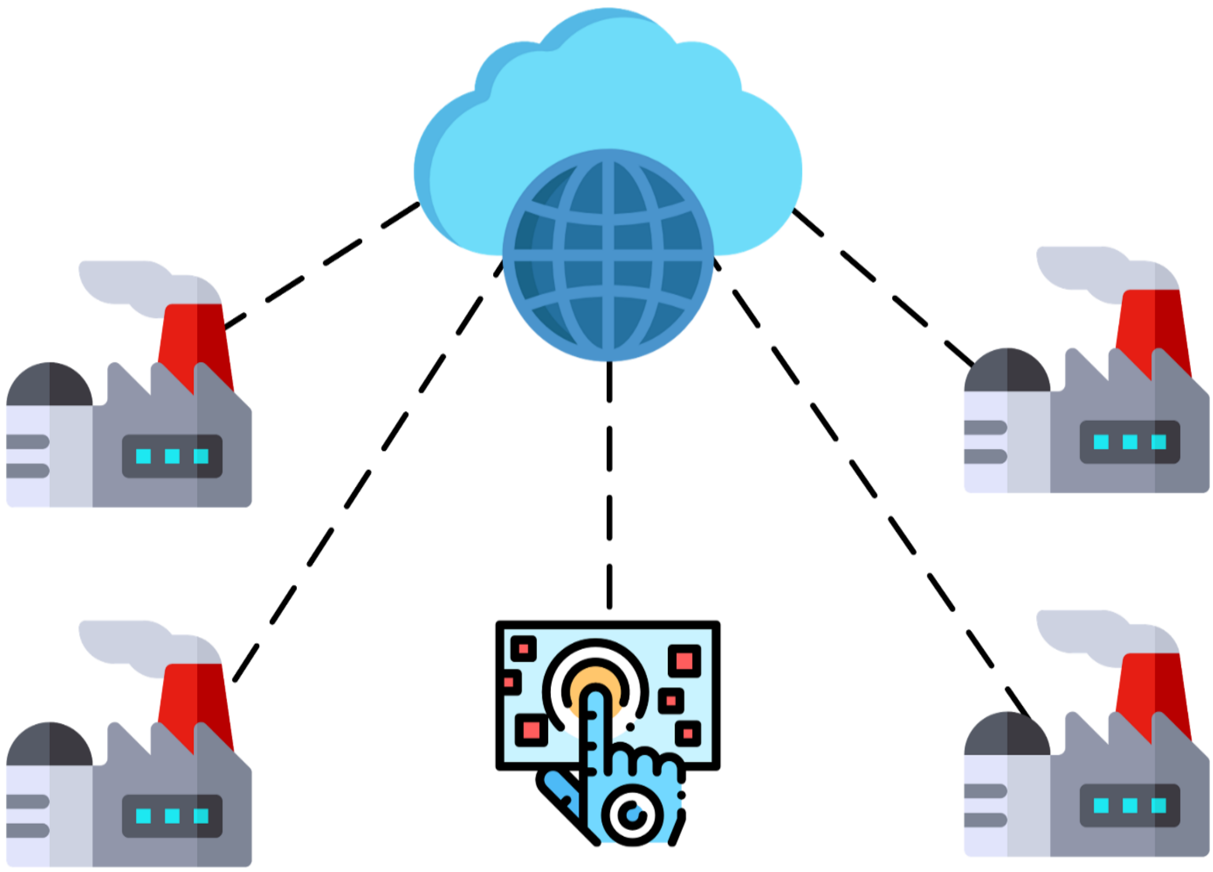

Figure 6.2: Globally Connected Factories

6.8 Regulatory/ Legislative changes required

Regulatory and legislative changes required by the Governments to address Industries 4.0 are:

6.8.1 Employment related

The use of AI, robotics and 3D printing overcome labour arbitrage creating massive unemployment in countries with low-cost workforces. Developed countries with lower population could reduce sub-contracting to lower wage highly populated countries, as they could implement automated factories in their own countries with lesser workforce. Automation leads to disruption in the current job market as businesses will require less workforce, creating large scale unemployment in underdeveloped or developing countries with large populations mainly dependent on labour market. This would create an imbalance in global society. Also, it could be a challenge legally to terminate employment contracts due to transition to Industries 4.0 [32].

Automation could lead to remarkably high production volumes leading to an excess supply and less demand, as the large-scale affordability would become reduced. This will totally change socio-economic political scenario all over the world

New digital skills will be required to implement Indiustries4.0. This creates an opportunity for highly skilled digital jobs. There will be huge demand for such talent. This creates demand on the existing employees to upskill and reskill. Government policies should include mandatory measures for employers to upskill/ cross skill existing workers so that there could be minimal impact of job losses. Also, policy should include increased investment in human capital and skills to enable industrial transformation. Governments should ensure that courses on advanced manufacturing are introduced in education institutions. The challenge to governments is far greater. New digital skills are needed where current educational curricula have become out-of-date. Governments can fund industry 4.0 investments, and leverage digital for workforce capacity building [33]. Innovations in e-learning like MOOCs and JIT training, product usability, shift to voice & visual interfaces are required. Labour law needs to be amended to allow flexible work time models [34].

6.8.2 Safety regulations

Industries 4.0 concept depends on autonomous devices and machines. Problems can arise due to malfunction of these autonomous devices and machines which can cause damage and injuries to workers. Here, we are not looking at faults created by human error but those caused by machines which are working autonomously. Governments should introduce strict safety regulations which should also address liability issues. The owner of such autonomous systems should be responsible and liable for any damage caused by the system. It can be expected that, as a greater number of autonomous systems are developed and used, more laws and regulations will need to be written to establish a strict liability on owners of such systems.

Cyber-attacks on the intelligent machines, could make machines behave erratically and may lead to material damage and worker injuries. Regulations should ensure that strict cyber security measures are put in place.

6.8.3 Data Privacy and Protection

If data represents a business/ trade secret or consists of personalized data, they need to be protected. Data espionage, phishing or data alterations should be protected with laws. Example: Germany provides such data protection by laws [35].

6.8.4 Standardization

Industry 4.0 requires an unprecedented degree of system integration across domain borders, hierarchy borders and life cycle phases. Standardisation is of central importance to its success because it will involve networking and integration of several different companies through value networks. This collaborative partnership will only be possible if a single set of common standards is developed. A neutral reference architecture is required to provide a technical description of these standards and facilitate their implementation.

Common international standards are required to facilitate industries to establish global networks of their machines, warehouses, and factories. Countries must take initiatives to establish such standards. Countries National Standard bodies should work with International Standards and there should be collaboration between various International Standardization bodies (like Industrial Internet Consortium/ ISO / IEC/IEEE/ ITU-T etc) to arrive at a common reference model

The initiative should bring industries, associations, academia, trade unions, policy makers etc together to coordinate implementation of Industries 4.0. Eg- Germany's "Plattform Industrie 4.0", Australia's initiative "Prime Minister's Industry 4.0 Taskforce" etc.

Germany's "Plattform Industrie 4.0" proposed one such model: Reference Architecture Model Industrie 4.0 (RAMI4.0), the objective of which is to set a comprehensive framework for the conceptual and structural design of Industry 4.0 systems. RAMI4.0 describes a reference architecture model in the form of a cubic layer model9 which provides an architecture for technical objects (assets) in the form of layers, and allows them to be described, tracked over their entire lifetime and assigned to technical and/or organisational hierarchies. It also describes the structure and function of Industry 4.0 components as essential parts of the virtual representation of assets [36].

6.8.5 Encouragement for development of Industries 4.0

AI plays a major role in this by giving the ability to spot potential problems and possible solutions even before a human operator would notice such issues. This results in positive improvements across their smart factories, reducing maintenance costs, as AI can now detect wear on machinery long before it becomes unmanageable. However, AI needs access to large amount of data to create data patterns. This could be expensive and only large international corporations may be at an unequal advantage. Government should regulate availability of data access so that smaller companies and start-ups are able to get access to real time data. UK Government is looking at implementing a "Open Banking" style model where some anonymized data can be made public to make the sector competitive [37].

6.8.6 Taxation

Current Taxation systems on industries looks at cost optimization strategies like providing tax incentives for investments, to transfer pricing regulations for complex supply chains. Industries 4.0 strategies are based on revenue and not cost, which may come from multiple sources with flexible supply chains for on-demand manufacturing and the shift from products to data-driven services. As supply networks become less centralized and more interconnected, it will be vital to consider where value is generated in a supply chain, how or where the value should be taxed, and which entity should be liable for the tax. The place where value is generated comes under the tax jurisdiction. In case of data-driven services, it would be debatable as to where this 'value' is generated—is it where the data is generated or where the data is enriched or where the data is analysed or where the data is ultimately used. Also, how do we calculate the value of data as data analytics would be done by machines without human intervention. This would involve regulators to put a value to each step of the process to enable more accurate tax planning.

There could be situations where product sales and aftermarket sales take place in different tax jurisdictions, the client may be generating data in a 3rd location and data may be analysed in a different location. It will be challenging as to where and how to tax these data-driven services. Also, products could now be sold through a service model, i.e supplier does not make supply of goods but leases these goods to its customers and charges for monitoring the performance of the goods and providing proactive servicing and maintenance. These could be challenging to tax frameworks.

In March 2018, the European Commission made two legislative proposals to address some of the challenges associated with taxing the digital economy. The first initiative aims to reform corporate tax rules so that profits are registered and taxed where businesses have significant interactions with users through digital channels. The second proposal looks to introduce a new indirect tax to capture digital services where the main value is created through user participation. Despite these advances, however, challenges remain across all the main types of tax used by industrialized economies [38].

Governments should understand the benefits brought about by Industries 4.0 and should work together in a co-ordinated manner, to create smart regulations to address global taxation issues.

6.9 Opportunity/ Value Capture in Industries 4.0

Industry 4.0 will eliminate the issue of distance to potential markets, often cited as a challenge for manufacturing companies. Manufacturers can reduce the cost and improve the value of the products they sell on global markets, and they can also improve their competitiveness by shifting their focus towards the highest-potential markets. Industry 4.0 will create an environment allowing collaborations between design houses, prototypes assemblers, test centres and production houses, all of which can be spread across the world to make use of the best of solutions and capabilities across the world.

Industry 4.0 allows manufacturers to shift their focus away from the initial sale of a physical product to a recurring revenue model, in the form of aftermarket support and maintenance. Connected products provide a constant stream of data back to the manufacturer, and by analysing this data, manufacturers can begin to anticipate demand, and enable capabilities such as predictive maintenance. In this way, the data provides opportunities to create additional value—and recurring streams of revenue—through complementary products and services. Concluding the sale is therefore no longer the end of a commercial process, but the first step toward a recurring flow of business.

One of the most profound characteristics of Industry 4.0 is the evolution from selling physical goods, often expensive assets, to selling data-driven services. This is different from the aftermarket, in that organizations can offer wholly new services and explore entirely new service-driven business models rather than simply adding services to the sale of a product.

Companies can create value by the way they implement the application areas of Industries 4.0 [39].

- Smart Manufacturing – Increases productivity by automation of production and processes. All operational data can be collected from sensors in machines and other equipment and analysed in real-time through AI/ML, to get dep insights from the collected data. These can provide value like predicting malfunctions before they happen or adapting process to changed production conditions.
- Connected Supply chain – Manufacturing is connected to other areas of the company like Sales, Customer Service to external Suppliers and Customers. Just-in-time manufacturing and customized manufacturing is made possible. This improved and automated coordination amongst all stakeholders, brings in more agility reducing idle and lead times and enables delivery assurance.

- Connected Products - Products can be connected, configured/provisioned, and remotely monitored. This can support preventive and predictive maintenance of the product at the Customer. This can also lead to “Product-as-a-services”, where customers pay only for how much they use the product.

In a survey conducted by BCG during 2016 on Industries 4.0 organisations, they found that more value is expected to result from productivity and cost improvement than from revenue growth. Value from reduction of manufacturing costs was the highest followed by improvement in product quality and operations agility. However, in this survey they found that the implementation was in Cybersecurity, big data and analytics and cloud computing. Implementation for additive manufacturing, advanced robotics and AR were still underway and the respondents indicated that these were their priority areas during the next two to three years. Regarding the challenges in implementing Industries 4.0, the response was lack of right talent and culture change as the biggest obstacles [40].

Other areas where Industries 4.0 is enabling value creation are:

- Quality Improvement – In a high-volume multi-product manufacturing industry, AR deployed at workstations shows Operators the correct assembly procedures for each product as they pass through the assembly line. This reduces assembly mistakes and improves quality.
- Productivity improvements – Collaborative robots or cobots can be deployed for tedious manual jobs and they can also be installed with vision systems to inspect parts. Productivity is increased as these cobots could work 24x7 and with consistent accuracy.
- Faster prototyping with 3D printing, reduces development costs and time.

New services can be created. Eg- “Tyres by the distance travelled”– Wireless sensors can be installed on tyres to gather data in real time on the tyre pressure, temperature, speed, fuel consumption. This data is analysed in cloud for its performance giving feedback about fuel consumption and this data is also used to charge customers for tyres based on the distance travelled**.**

The opportunity of improving manufacturing processes is enabled by connectivity through smart sensors and real-time transmissions. Establishment of 5G network creates a truly automated factory, as this network can provide connectivity with the requisite latency and bandwidth to manage machines, sensors, materials, and robots. The potential for improving production economics for manufacturing is great when introducing high performance connectivity to the factory floor.

The opportunity/ value capture can be demonstrated by the project conducted by Fraunhofer Institute for Production Technology and Ericsson [41]. They have collaborated to research new methods for improving process control and predicting manufacturing failures and found that introduction of 5G into manufacturing could be the answer by allowing connectivity and automation on the factory floor in an unpreceded scale. Rework has been the main problem in high-precision metal manufacturing. Decrease in rework rate through automation can lead to significant savings in money. This case study considered one of the most demanding metal processing applications like manufacturing of bladed disks (BLISKs) which are important components of turbines such as aircraft jet engines. The Fraunhofer IPT project tested automated production, monitoring and real-time control of the BLISK production process to identify issues and areas where improvements could be made by introducing intelligence to the system. They did this in 4 steps – First they enabled monitoring and data collection to optimize future milling. Then they enabled real-time monitoring to stop defective parts from further processing. Further they enabled real-time control to adjust the process in motion, for example by altering the milling tool spinning speed. They were able to enable a fully automated factory by connecting all devices and managed as one ecosystem. They were able to reduce the rework rate from 25% to 15%, which resulted in a machine cost reduction of Euro 3600 per BLISK.

The main benefit of 5G in this use case was that it provided very low, stable and predictable latency. 1 millisecond was the ultra-low latency needed for real-time control of the BLISK manufacturing process. 5G enabled the control loop by providing this low latency capability, enabling its application in BLISK production. Miniaturized sensors and 5G communication modules are also critical to wireless data collection and the communication capability for cases like this one. The introduction of 5G will also bring more tightly controlled monitoring capabilities, meaning that the performance of a critical sensor, such as the BLISK vibration sensor, can always be monitored.

The FIPT research has concluded that with the assumption of global production of 100,000 BLISKs, there could be an annual machine cost saving of Euro 360 million made on BLISK production through 5G-enabled real-time monitoring and control. The reduction in production time amounts to reduced electricity consumption and reduction in CO2 emissions. This is a representative example of similar problems faced in manufacturing industries and implementing 5G could help solve them. – Equipping each industrial site with mobile communications opens large opportunities for operators to expand their business. The project study finally concluded that 5G helps industrial manufacturing processes.

6.10 Business Models for Industries 4.0

Industries 4.0 enables new Business Models which can disrupt existing way of doing business and result in leap frogging in business outcomes. Manufacturing organisations and businesses should harness the enabling technologies behind Industries 4.0 and update their business models to ensure business sustainability. Business models should include data driven services and integrated platform solutions.

The business model should fully harness the capabilities of 5G enabled Industries 4.0 features in the complete product life cycle. The product conceptualization and design should happen in a simulated laboratory and a small prototype batch should be built using 3D printing. Testing of the product should happen in the market environment using simulation techniques enabled by Virtual and Augmented reality. It should include robotic manufacturing processes to handle all routine and repetitive jobs. All operations of the industry should be available for remote monitoring and control. Predictive maintenance should be part of the model.

The model should include partnership with global vendors, remote factories, and customers, to form a global value chain partnership model or the Connected Factories model. These new Business Models should handle individual customer needs and integrate supply chain networks with vendors and business partners. It should include effective collaboration between remote workers, multiple geographies, global supply chain management and global market.

The business model should consider a holistic view of the product lifecycle, analyse the shrinking boundaries between physical product and services and look at 'Product as a Service' model and "Pay as you need" pricing model. The model can include "**Production-as-a -Service'** offering which is a data driven service where the part producer does not own or operate any machines but only pays for the parts produced for him.

The industry does not have to invest on expensive robots as it will be challenging to learn the operation and be responsible for its operation and maintenance. They could hire or lease robots for a fixed amount of time and costs. **Robots as a Service** model enables the Industry to hire robots when they want to manufacture some part, without owning them. The robot service provider owns, operates, and maintains the robot [42].

"Equipment-as-a-Service' Business Model:

The traditional business models of an industrial machine manufacturer are to sell equipment to the operator and offer maintenance service as part of the annual maintenance contract. Operators today are looking at balancing their OPEX and CAPEX. Rather than owning equipment, they are renting the equipment. This opens a new business model for manufacturers. Manufacturers can now offer equipment as service. For ensuring the machine availability and output that the client is expecting, it is required to monitor the equipment remotely and ensure timely maintenance to avoid loss of revenue. Proactive maintenance planning can help manufacturer offering this new service, reduce their own operational cost.

The business model should support energy management to reduce costs. The energy consumption pattern of individual machines and the factory should be analysed, and the machines should be programmed to work during time of day when energy tariffs are low. This will help in effective energy management.

Mobile Operators could harness the Industries 4.0 business opportunities by innovating their business models based on Service Level Agreements rather than subscriptions. They should work together with major factory ecosystem suppliers to help Industry 4.0 take off by establishing one unified form of communication technology. Based around high-value use cases, this would make it easy for a customer to choose a private enterprise cellular connectivity solution. Being early in offering a unified solution could build momentum in an expanding market and would also accelerate mobile communications' progress into the selection of available options. To address the large business opportunity, Operators need to:

- Package an easy-to-buy, off-the-shelf commercial solution
- Build a delivery organization that responds to strict SLAs
- Gain market awareness of the deployment challenges and ecosystem properties affecting customers

The business model should reposition the Industry as a Digital Manufacturing Services Provider or Digital Industry taking it to the factory of the future.

Industries 4.0 Business Model

The author has defined the 'Industries 4.0' Business model based on the Seven Dimensions of Business Model [43].

Value proposition - 'Product as a Service', 'Production as a Service', 'Robot as a Service', Predictive Maintenance

Customers or Users – Buyers of finished products, another industry requiring some part of their product to be manufactured here, some customers requiring lease of robots for a particular task and fixed duration.

Value chain functions – New Industries 4.0 enabling technologies like sensor network, embedded systems, collaborative robots, 3D printing, AR/VR, big data, cloud enabled by 5G connectivity would be introduced.

Competences – Knowledge of digital manufacturing, Adaptability to automation assisted manufacturing, AI, Big data and Predictive analytics development.

Network – IT infrastructure partners, telecom service providers, AR/VR specialists, Vendors of manufacturing equipment and tools, Data Analytics developers.

Value formula – Direct purchase price of products, Performance based revenues, cost optimization derived from better use of resources and processes.

Relations – Integrated IT systems connecting suppliers, vendors, customers to the manufacturing network.

The way the Industry creates, delivers and captures value, can be based on Osterwalder et al., framework of business model definitions.

These are represented in Figure 6.3 below.

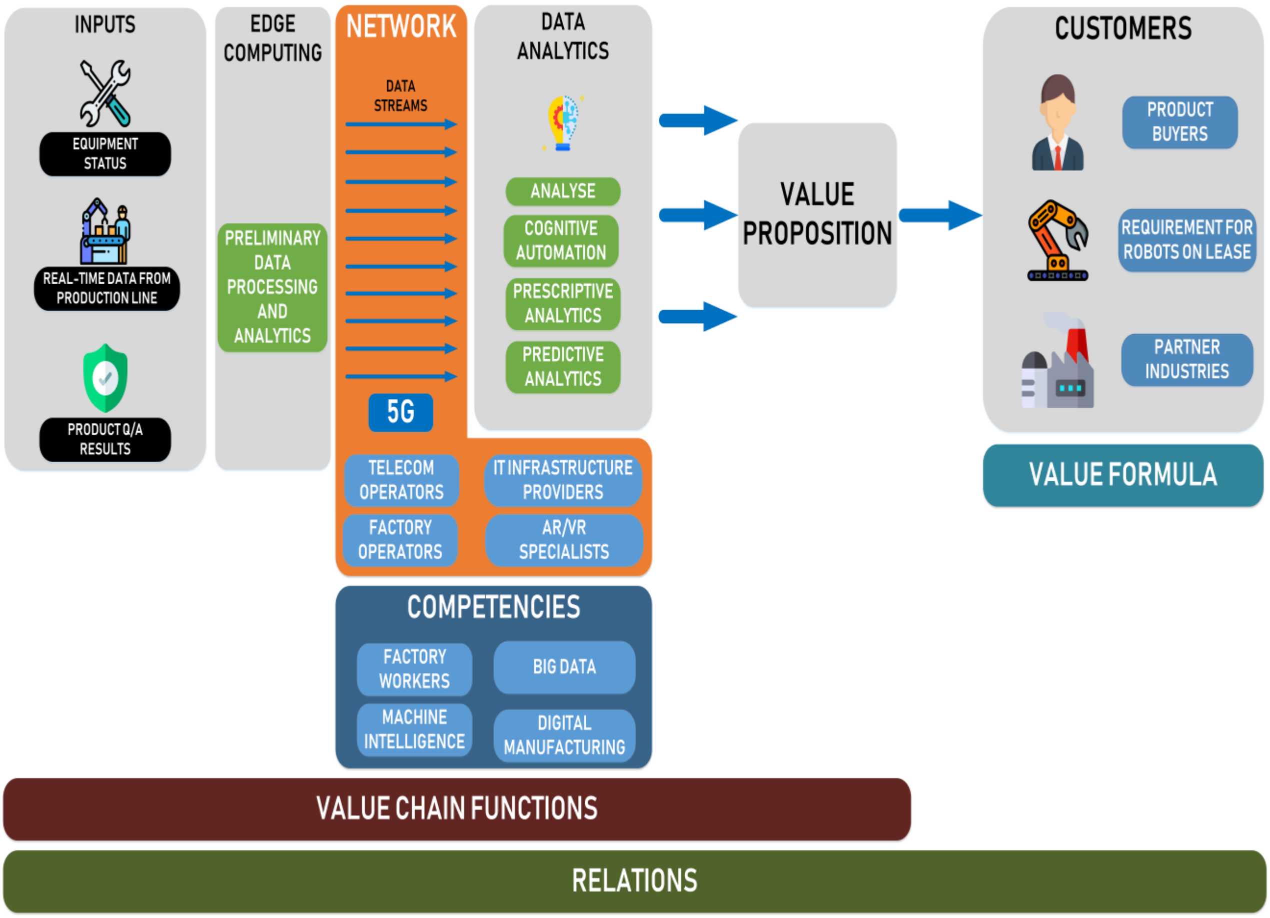

Figure 6.3: “Industries 4.0” Business Model

The value creation, value delivery and value capture in Industries 4.0 is shown in Table 6.1 below

BM DIMENSION	**VALUE CREATION**	**VALUE DELIVERY**	**VALUE CAPTURE**
Value Chain functions improvements	Improved products, High volume manufacturing, Production as service, Robot as a service,	Just-in-time supply chain, predictive maintenance. Product upgrade activation, spare part ordering and replenishment.	Low inventory, cost optimization
Customer	New customized products and services	Higher Customer Satisfaction.; Co-creation with customers by engaging them in value creation.	New revenues – dynamic pricing; performance-based revenues and incentives.
Network	ICT systems connecting their factories spread across different regions, connecting factories with partners and vendors networks, all leading to real-time information about production, sales, resources, inventories etc.	More versions of products; Ability to expand market reach and get new customers.; building direct relations with customers, vendors, telecom operators.	All network partners benefitted

TABLE 6.1: Value Creation, Delivery and Capture in Industries 4.0

6.11 Examples of implementation:

- Intel showcased Industries 4.0 with 5G, at the recent Mobile World Congress (MWC) 2019. They successfully demonstrated 5G-connected robotic arms performing tasks within a virtual safety case, which received real-time guidance using cameras equipped with AI technologies. These capabilities were integrated with multi-access computing (MEC) processing to monitor movement and shut down operations when workers enter a danger zone. 5G empowers Intel technologies such as Open Visual Inference & Neural Network Optimization toolkit, which allows manufacturers and developers the flexibility and ease to optimize and deploy AI anywhere, including Intel based industrial PCs, and capitalize on near real-time insights for better, faster decision-making. Intel is driving the industrial sector forward by enabling massive operational efficiencies and safety improvements M2M automation, machine vision, and AI insights, supported by ultra-low latency connectivity over Intel-powered transformed 5G and edge networks. IoT sensors, devices, and robots can connect to edge resources, leveraging data to revolutionize the supply chain from the factory floor to the customer [44].

- Spanish automotive supplier Gestamp Automocion SL implemented Siemens a Predictive analytics solution -Energy Efficiency Application. They were able to reduce energy consumption by 15% and saved Euro 8M in energy bills [45].

- Siemens EEA solution analyses consumption patterns to detect machine's performance the accuracy of its settings. This ensures smooth operations which can be translated into fewer failures and a longer life of the machine. The information can be used to select the type of energy tariff and negotiate power consumption contracts based on actual needs. The optimized energy contracts can result in cost savings. Production schedules can be mapped with energy consumption which gives rise to 40% decrease in energy consumption [46].

- Nokia has implemented 5G standalone wireless network for industrial clients. It has an order to build one for a mining company Sandvik in Finland. They are also addressing most demanding of use cases such as automotive manufacturing where cloud, robotics and autonomous machine operations create mission-critical demands for reliable low latency and high data rates [47].

- Qualcomm provided live demonstrations of 5G IIoT capabilities such as Time Sensitive Networking (TSN) , enhanced ultra-reliability low latency communication (eURLLC) and precise indoor positioning, Johm Smee -VP of Engineering of Qualcomm blogged that it can deliver up to 99.9999% reliability with low and deterministic latency [48].

- Qualcomm demonstrated 5G network in a small production line setup at San Diego warehouse and showed that all the objects are recognised, in spite of industry and manufacturing environments having numerous metal structures and barriers posing a challenge for traditional network layouts blocking the radio link paths. The positioning support of 5G in form of round-trip time (RTT), angle of arrival/departure (AoA/AoD), and time difference of arrival (TDOA) improved the accuracy of locating device positions. Rel-17 is further enhancing positioning latency, capacity and accuracy down to cm-level, which will be important to IIoT use cases. The precise positioning is very important for industrial operations like asset tracking and AGV control. This was demonstrated at Qualcomm. Qualcomm concludes that with these new capabilities are “going to open a huge opportunity for the next industry revolution in term of flexible manufacturing and productivity increase [48].

- Siemens has embraced Industrial 5G right from the start and is supporting its standardization and industrial implementation by developing a corresponding portfolio, according to Klaus Helmrich, Managing Board Member. It has setup a private standalone 5G network at its Automotive Test Centre in Germany in collaboration with Qualcomm, to test concrete industrial applications with 5G such as automated guided vehicles (AGVs) for smart production, logistics and flexible manufacturing. Features like reliability of communications and latency are tested under actual industrial conditions [49].

- British Telecoms has implemented a private 5G network at Worcester Bosch factory with technology from Ericsson, leading the UK’s Industries 4.0 agenda. This will support all latest IIoT including sensors, wearables, data analytics, robotics, augmented reality, plus variously localised edge, multi-access edge (MEC) work in perfect harmony to gather and interpret the vast volumes of data generated by connected machines and turning this into real-time and actionable insight. Gerry McQuade, chief executive of the company’s enterprise business, has stated that they are creating a smart factory where machines can learn and adapt to changes on the factory floor as they happen, and make instant, autonomous decisions to optimise the production line and this has been made only possible by harnessing 5G private networks, IoT, data analytics, and mobile edge computing. . Worcester Bosch said factory output is up by two per cent since the 5G network was switched on [50].

- The UK Govt is promoting the above model to boost productivity in the region. They have also funded “5G Encode initiative” in Bristol, which is presented as the UK’s largest trial of Industrial 5G. This project will investigate three key industrial 5G use cases to improve productivity and effectiveness: interactive AR & VR; asset tracking across multiple sites and locations; and industrial system management [50].

- A survey conducted by OMDIA during May 2019 with senior management team of large global manufacturing industries having plan and strategy for 5G, revealed the following:
    - Respondents believed that 5G will increase situational awareness and flexibility in the factory floor.
    - 80% of respondents stated their organization uses wireless networks on the factory floor, with nearly half (46%) said they are using these technologies in some mission critical applications

- Security was the top requirement for network connectivity solutions
- Majority of the respondents stated that they have already invested or planni8ng to invest in technologies which can being in flexibility in the factory.

With this survey, Omdia's expectation of the applications of 5G on the shop floor were Quality management using machine vision, Automated Guided Vehicles, VR applications, fleet management and asset monitoring. that 5G can address security concerns through network slicing and private networks. The survey concluded that 5G can address key industrial requirements like network availability and scalability and can enable flexibility in factory [51].

6.12 Summary

The current communication systems like 3G/4G LTE has limitations in supporting the stringent requirements of Industries 4.0. The proposed features of 5G like its high speed, low latency, low power requirement, massive machine type communication, network slicing, ultra-high reliability, scalability etc. are required to fulfill the vision of Industries 4.0. 5G supports Industrial Internet of Things, which forms the backbone of Industries 4.0. These features enable the automation of the machinery and processes and brings in flexibility of process scheduling, enhancing the productivity of operations and reduction of costs. It enables remote control of factories and global connectivity of factories to form a global value chain.

Information and knowledge sharing throughout the production lifecycle is automated by the ultra-low latency and high reliability offered by 5G, leading to enhanced manufacturing efficiency. The virtual reality and augmented reality functions enabled by 5G, helps in predictive maintenance which reduces repair costs of equipment's and process downtime. It also enables efficient energy management.

5G promises to be a key enabler for Factories of the Future, providing unified communication platform needed to disrupt with new business models and to overcome the shortcomings of current communication technologies.

On the social side, there would be disruption in the current job market as businesses will require less workforce. New digital skills will be required to implement Indiustries4.0. This creates an opportunity for highly skilled digital jobs. This creates demand on the existing employees to upskill and reskill. Also, automation leads to developed countries manufacturing in their own places and reducing sub-contracting to lower wage highly populated countries. This creates an imbalance in global society. There could be large scale unemployment in underdeveloped or developing countries with large populations, who are mainly dependent on labour market. Also, automation could lead to very high production volumes leading to an excess supply and less demand, as the large-scale affordability would become reduced. This will totally change socio-economic political scenario all over the world.

Industry leaders and Regulators will have to address the re-skilling of workers to address the social problems.

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7.0 Socio Economic Impact of 5G on Smart Energy

7.1 Introduction

Electricity is a very crucial requirement for the socio-economic growth of a nation. Electricity generation, transmission and distribution methods are changing with large scale renewable generation. This has resulted in the need for Smart Energy management consisting of Smart grids and smart metering. Smart grid introduces seamless integration of emerging technologies in the field of monitoring, automation, communication, and IT systems. Some of the features of Smart Grid are Advanced Metering Infrastructure, Outage Management System, Power Quality Management, Demand response/ demand side management, Energy storage, Micro grid, Asset management etc.

Smart Energy enabled by 5G technologies, will shift many of the centralized command and control towards a mix of central and distributed control structure, giving more power to the end consumer on the choice of energy consumption and greater control on their utilization of power. The objective is to enhance optimal and efficient delivery of energy.

In this chapter, the global trends in smart energy is explored. The consumer, business and regulatory demands are analysed. The features of 5G in meeting these demands are discussed. The social and business impact of 5G enabled Smart Energy, are analysed. The business models to be followed by Utilities and Private energy producers are presented.

7.2 Global Trends in Smart Energy

The global trend includes greater energy demand and increased awareness and regulation for adopting green energy and reduce CO2 emissions. Solar energy is increasing being adopted by developing countries, with the cost of the Solar Photovoltaic (PV) systems getting lower fuelled by increasing utilization. The battery costs are also dropping down.

International Electrical Agency in its 2017 World Energy Outlook, estimated that the costs of new Solar PV have reduced by 70% from 2010 till 2016, whereas the costs of wind energy have come down only by 25% in the same period. The battery costs have come down by 40%. There is great rise in the Solar PV generation. China and India are the key countries driving these energy demands. The expected demand from India alone is 30%. Renewables capture 2/3rd of global investment in power plants as they are the least cost source of power generation in many countries. The solar deployments led by India and China, will make the share of all renewables in total power generation reach 40%. In EU, renewables will account for 80% of new capacity and wind power would become the leading source of electricity after

2030. China has 1/3rd of the global wind and solar PV installation and accounts for more than 40% of global investment in Electric Vehicles [1].

Countries are embracing smart grid technologies across the world. The need to replace old legacy infrastructure, government's policies, and increased consumer awareness, is leading its implementation. It is expected to grow exponentially as per the estimates of various research analysts.

- Global Industry Analysts predicts that the global market for Smart Grid technologies and services is projected to exceed US$ 75 billion by 2020. The fastest growing market in the world will be APAC with a CAGR of 13.7%. The main investors in smart grids are China and US. China is expected to have 100% deployment of smart electricity meters by 2020 [2].

- PRNewswire in its report dated 10 Jan 2017, estimates that smart grid market size will grow from USD 19.77 billion in 2016 to USD 65.42 billion by 2021 at a CAGR of 27%. Major countries contributing to the growth of smart grid technologies include US, China, Japan, India, Australia, Singapore, New Zealand and South Korea [3].

- Scalar Market Research estimates that the smart grid market will grow from USD 39.84 billion in 2016 to USD 83.81 billion in 2022 at a CAGR of 13.2% [4].

- Transparency Market Research in its Jul 2016 report predicts that the global revenue of smart grid market to rise to USD 118.13 billion by 2019 with a CAGR of 18.2% from 2013 to 2019, with APAC having 47% market share followed by US having 21% market share [5].

The current electricity networks have been designed for "unidirectional" flow of electricity, revenue, and information. In a smart grid (inherently enabled by M2M communications), consumers would generate electricity and become 'prosumers' wherein, they would be able to feed electricity back into the grid and generate revenue. M2M communications would help in monitoring and controlling these intermittent, unpredictable, and dispersed sources of generation. Smart metering would benefit both, consumers, and utilities by enabling remote reading, connection/disconnection, load control via time of day/time of use prices, detecting outages early etc. The rollout of Smart Meters is important for the smart grid network stability.

- It is estimated that US had more than 75 million smart meters installed by 2017 and EU had a target of replacing at least 80% of the conventional electricity meters with Smart meters by 2020 [6].
- IEA had estimated a global installation of around 700 million smart meters by end of 2016, with China having approximately half of that alone [7].

Data exchange will increase considerably in Smart grids, giving rise to security issues. It is predicted that the global smart grid security market will grow at a CAGR of 10.5% during the period 2017-2025 to become worth US$10.58 billion by 2025 from US$4.35 billion in 2016 [8].
Electricity power storage system cost is also decreasing to levels affordable to consumers. It is expected that developed countries and developing countries would enhance their smart grid network further in years to come.

7.3 Drivers for Smart Energy

7.3.1 Consumer Driver

Consumers demand that energy and communications are a fundamental right like water and they are not luxuries. There is growing need for higher consumption of energy, due to new types of home appliances being introduced for convenience and better standard of living. Consumers want good quality, reliable and continuous power so that they do not have to use unnecessary add-ons like voltage stabilizers, Uninterruptible Power Supplies etc. There should be zero or a near-zero outage and very minimal planned downtime during maintenance. They would also want to generate alternate energy like roof top solar PV, use it for their consumption and put excess back into the grid. i.e. they want to become Prosumers or both producers and consumers of energy. By this, they could reduce their home electricity bills and even earn additional revenue if they are able to put back excess into the grid.

Consumers demand flexibility of pricing based on usage at times when peak consumption is low. They should be able to view their consumption of electricity accurately on a regular basis. They should be able to remotely turn On /Off their appliances and manage to make use of the 'Time of Use' tariffs by shifting non-priority loads. This could save money for them.

Consumers want to store electric power as a commodity, due to the decreasing costs associated with storing. Consumers demand environment friendly power or green energy, which reduces carbon dioxide emission. Ultimately, consumers demand privacy and security as critical information about their place is being communicated.

7.3.2 Business Drivers

Electricity was the monopoly of governments of many countries and is continuing to be so. The utility would have installed infrastructure on a long-term basis and this legacy infrastructure is ageing and inefficient, which would need replacement. Countries are becoming environmentally aware and bringing in regulations to reduce and control CO_2 emissions. This drives the demand for cleaner source of energy or renewable energy from sources like solar and wind. Incumbent large government owned power companies may have to switch to their production to reduce carbon dioxide emissions and include renewable energy sources, which demands huge investments.

Renewable production depends on weather conditions and varies during the production cycle. To optimize its usage, dynamic routing of electricity is needed which in turn needs real-time supervision and control network. Data from various devices need to be transmitted and processed in real time. The communication network should support all these services by providing virtual network functions to provide unique network performances with related SLAs specifying latency for these sectors.

With consumers becoming prosumers, i.e. generator of power, leads to a situation of the utility companies to manage millions of small producers. This also leads to instability of production and usage and utility companies must plan for this. Large users of power, like large industries/ data centres etc, may opt to produce their power through renewable sources. Also, many companies may join and generate their own power and share it. This joint production may give rise to better and lower cost of production. They may develop their customised management systems to share the production costs and usage.

Technology advancements aided by de-regulation, has enabled Consumers to generate their energy requirements. Many countries are now encouraging Consumers to install Solar PV and generate energy for their use and put back excess generated into the grid. So, Consumers are turning into Prosumers I.e. both producers and consumers of energy. The energy sector which hitherto had only incumbent large utility company, will have to integrate new energy producers entering the sector due to these technology advancements and de-regulation. There is a demand to supplement the large utilities which controlled generation, transmission and distribution with smaller distributed generation which is close to the point of consumption. The demand is also for efficient storage of energy at lower costs.

Prosumer behaviour also needs to be considered here. The demand for electricity as a share of the overall energy consumption will increase in the future, due to increased affordability of HVAC system and electric vehicles. Consumer’s behaviour plays a big part in increasing the demand. De-regulation of power generation has led to many consumers becoming prosumers. Central power companies must model the behaviour of the electricity prosumers to plan the load balancing of the grid [9].

Individual’s personal belief systems, basic values, interests, and objectives play a role in their behaviour as a prosumer. Behaviour could also be contextual and influenced by the prosumers’ economic status like availability of finance/funds, ownership of electric vehicles and large number of heaters/ACs, etc. It would also be heavily influenced by the extremity of weather conditions in that area like being too hot or too cold. Unreliable central power supply may influence them to produce their own requirement aided with consumer-friendly regulations. Modelling of the behaviour would involve predictive analysis of the above-mentioned influences and consider the flexibility of the prosumers to adjust their demand for power by shifting to off-peak hours. Prosumer behaviour can be influenced by the regulator's encouragement in terms of information, education regarding the technology, incentives/ subsidies to produce, guarantees of buy back etc. Dynamic tariff-based control of the power system plays a significant role in Prosumer behaviour. Price could be based on time-of-use and weather conditions. Residential usage is more during mornings and post evenings. Also, demand would be more during extreme weather conditions, during which times tariff could be higher. This could influence the prosumer's behaviour to utilize self-generated power during such high tariff periods.

Utilities have millions of consumers and hence millions of meters to record the electricity usage of each consumer. Every Smart Meter should be able to be addressed uniquely to make them reachable, accessible, and controllable from a remote central location. Enhanced security protection should be implemented in an end-to-end network. The huge growth of connected mobile devices for various applications, would result in unpredictable usage of power, which needs to be managed and the energy consumption of these devices need to be controlled to ensure energy efficiency.

Business needs ICT Technologies to allow two-way communication between utilities and millions of end consumers, collect huge amount of data in real time, process it and command appropriate actions. The various function elements of smart grid should communicate with each other with low latencies for efficient fault management and power restoration. It must ensure system reliability and quality of service. The system should enable transparent consumption and pricing for the end user.

Smart grid providers plan and implement their system with a longer-term perspective and cannot change or upgrade their system in tune with technology advancements, as it would prove expensive doing so. So, they want the telecom infrastructure to be robust, secure, reliable, and future proof ensuring long term availability and cost stability. Security and availability of telecom network is of prime importance due to the mission critical requirements of the smart grid.

The increasing number of connected devices creates a demand for efficient Asset Management, and a quick provisioning of these devices. The coverage area of the system should include inside buildings in densely populated metros to remote rural areas and the communication system should assure ubiquitous coverage. The growing demand for Electric Vehicles needs that they need to be integrated into the energy system. Electric energy trading would require high speed low latency telecommunication networks.

7.4 Technology Enabler

Smart grid technology will support accurate, real-time analysis of power consumed and power outages. Smart Grid includes diverse use cases ranging from system protection that requires ultra-reliable and low latency communication to Smart Meters that require support of massive number of networks connected devices with relaxed latency and reliability requirements. Energy sector would see a huge proliferation of data which needs to be managed by the communication network. Smart grid has been experimented with 3G and 4G/LTE technologies. However, their design targets were primarily for support of mobile broadband services requiring very high user data rates. Smart grids have stringent end-to-end latency and reliability requirements along with high very data rates, which is not possible with the existing technologies. The network must not only support wide areas but should also penetrate to reach basements in highly dense area. The simultaneous support of low latency, ultra-high reliability, availability, and very high data rates is not available in the current technologies as they were not originally designed for critical application. Also, the design must support unexpected massive traffic increase, when large number of devices start communicating at the same time due to some fault condition. This needs a flexible network which can handle all the above scenarios. There is a limitation of deploying fibre optic links in densely populated urban areas due to construction limitations.

5G technologies would be a better fit for such diverse requirements due their flexible performances and their ability to deliver network slices and distributed cloud resources.
The features of 5G which could be harnessed in Energy sector are:

- Latency of less than 1mSec
- Reliability boost by combing several wireless technologies
- Enhanced security
- Enablement of new business models
- Operation in both licensed and unlicensed frequency bands. Benefits of licensed bands would be less interference from other wireless systems leading to better resilience and useful in mission critical applications. Some use cases not requiring stringent needs, may be ok with unlicensed band which does not require license fee.
- Massive machine type communication (MTC) including D2D, interoperability with satellite-based systems as a means of extension of coverage. This feature of extending coverage especially indoor and in rural areas would be very useful for smart grid applications.
- Massive MIMO- where large number of antennas are used to increase the reliability of the link and to extend the coverage. This suits the need of smart grid applications.

5G will make IoT more efficient with regards to spectrum as machines can use 5G network resources and associated spectrum only when needed giving the benefits of efficient use of expensive spectrum to the network operator and optimum energy consumption for the devices. 5G would enable additional low-cost device connections, so that detailed coverage of the energy grid could be made possible. With 5G, very large number of unconnected energy devices can be monitored and controlled in real-time to allow accurate forecasting of power demands, by their integration into the grid. This could help in load balancing and probable reduction in energy cost to the houses. 5G can enable Smart Street Lighting, as the multitude of devices and sensors in the street can track pedestrians or vehicles in real-time and lower public lighting during times when there are no pedestrians or vehicles in the street.

The communication network domains in the Smart Grids context where 5G is immediately expected to play a significant role are the access and backhaul networks. In future 5G might also play a role in other network domains like the backbone network domain which has the most stringent requirements in terms of real-time and reliability. The access network has communicating devices in the low voltage area, typically Smart Meters. The coverage area is less. The requirements could be less stringent. Very low bandwidth will suffice for the residential user and the end to end latency is also relaxed. The backhaul network has communicating end points in the medium voltage area like the secondary substations. This is characterized by critical applications like automatic fault detection and isolation for preventing power outages, and requires reliable, secure, and real-time communications which supports SLAs. The bandwidth requirements are higher than that in case of access network and the end-to end latency is much stringent in the order of less than 50ms.

5G enables switching between different communication technologies which ensures failure does not happen at the same time. The backbone network domain is typically between primary substations which needs very large coverage area. The important feature are protection functions which require ultra-reliable, secure, real-time capable communication. 5G features with its diverse functionality, supports the communication needs of the energy sector. Efficient integration of the 5G access technologies include multi-connectivity approaches where the user equipment is simultaneously connected to several access technologies or frequency bands which could help to address the requirements in terms of crisis handling. Outages can be quickly resolved reducing downtime.

There is a complex web of interactions between the electricity smart grid and the communications networks, each one in need of the other. The smart grid becomes more flexible and efficient but critically depends on the availability of high-quality data collection, transmission and analysis for operations and marketing. This communication need is met by the high speed and low latency features of 5G.

Different elements of the Smart Grid could be customized with regards to their data communication, signalling and power consumption needs. This customization would benefit the Operators as they would be able to optimize the network resources and performance accordingly leading to cost savings.
5G's network slicing feature enables virtual network functions and benefits the Smart Grid Operator to get guaranteed service level with regards to telecommunication availability and performance. Network resources could be flexibly provisioned to different services. 5G enables longevity of the network as it is compatible to older networks and is future proof.

The mission critical smart grid applications are expected to work without any interruption even in case of power outage. Current telecom networks may not be able to deliver this kind of resilience. The low latency feature of 5G enables protective functions to communicate with each other during a fault or outage situation. The interrupt free monitoring leads to quick fault isolation and rectification.

5G enables real-time communications between Electric Vehicles and charging stations which ensures smooth movement of Electric Vehicles. This enables integration of Electric Vehicles into the Energy systems.

All the above features make 5G the technology enabler for the mission critical communication within the smart grid.

7.5 Socio-Economic Impact

7.5.1 Social Impact

The power sector which used to be centrally controlled, would change to become user centric. Consumers would have the option to become Prosumers now, i.e they can also produce energy as well as consume it. They could install roof top solar PV and generate energy for their own consumption and put excess generated back into the grid and earn revenue for it.

They have better choice of the quality of service. They are assured of improved quality and reliability of power supply. They do not have to invest on unnecessary accessories like voltage stabilizers, uninterrupted power supplies etc. With the advent of the Advanced Metering Infrastructure (AMI), they would be able to view their consumption of electricity accurately on a regular basis and manage loads based on Time of Use (ToU) i.e use appliances when tariffs are low. They could save money on their electricity bills by shifting loads from peak hours to non-peak hours. They would be able to remotely turn ON/OFF their appliances.

They would have the flexibility in purchasing power from different sources including renewable energy. With the efficiency in energy supply, they would face reduced outages and downtimes, and even lower or zero load-shedding. With the ease of charging Electric Vehicles (EV) now, people could switch on environmentally friendly EV and thereby contribute to the reduction of pollution.

Various countries and regions have taken regulatory and legislative initiatives supporting smart grids.

7.5.1.1 Regulatory/ legislative initiatives in energy sector-- India

Earlier in India, the power sector was state owned. In 1991, private companies were allowed to setup generating facilities and sell in bulk to the grid or others, with attractive financial and administrative reforms, resulting in a rapid growth of energy production by private companies [10]. Currently, Government is planning to sell about its 149 small and marginal oil & gas fields to private & foreign companies [11]. The 'National Renewable Energy Act 2015' [12] promotes the use of decentralised and stand-alone renewable energy applications in rural and urban areas, with incentive and facilitation framework ensuring that reliable safe supply at reasonable tariffs are provided to end consumers. Any company may establish, operate and maintain a generating station without obtaining a licence, if it complies with the technical standards relating to connectivity with the grid.
The "National Wind-Solar Hybrid Policy" in 2018, defines the renewable energy regulations with a target of reaching 175 GW of installed capacity from renewable energy sources by the year 2022, which includes 100 GW of solar and 60 GW of wind power capacity. Policy provides a framework along with incentives, for promotion of large grid connected wind-solar PV hybrid system for optimal and efficient utilization and aims to encourage new technologies and methods involving combined operation of wind and solar PV plants [13].

7.5.1.2 Regulatory/ legislative initiatives in energy sector-- Europe

BRIDGE, a European Commission initiative fostering continuous knowledge sharing amongst projects, recommends that there should be regulatory flexibility to allow different parties to conditionally experiment with the deployment of energy storage for a temporary period. Legal framework should specify that network operators should be incentivised to procure services required for optimum operation electricity systems including storage services [14]. BRIDGE recommends that EU countries follow multi-building storage sharing which could open market opportunity for energy storage technologies and increase the deployment potential. Batteries representing significant economic costs, regulation would promote second life use of batteries, so that they are not considered as waste. To enhance re-use activities, the regulatory framework would allow shifting the responsibility from the initial producer to the professional "second-life operator". Changes in the energy have created a new market context. In particular, the participation of resources connected to the distribution grid is driving innovations in the energy system. Energy islands with large areas like a gated community or an independent large geographical area, could have its own smart energy system. This could include local renewable energy generation, smart distribution, and energy storage. This independent energy network can operate as a totally isolated grid or maybe connected to the national grid.

7.5.2 Economic Impact

The incumbent utilities will have to change production technologies to move away from fossil-based fuels to include renewable natural resources, as they must reduce CO2 emissions. This would involve massive re-investments. The hitherto centralised system will have to include, integrate, and co-exist with private energy producers who are entering this field supported by deregulations and new enabling technologies. These large utilities which controlled generation, transmission and distribution must integrate with smaller distributed generation which is close to the point of consumption. The impact is that the earlier centralised system will become decentralized having many small energy producers along with the large utility companies. Also, heavy consumers like data centres, industries etc can now produce their own power for their personal consumption without having the dependencies of large government owned utilities. These consumers can now share or sell the excess power generated.

This scenario of consumers becoming producers, will impact the large utilities resulting in production and usage becoming less stable and predictable.

The smart energy management ensures that the ever-increasing number of mobile connected devices, can be managed for their energy consumption. This results in scalability of connected devices. Real-time data acquisition from millions or billions of connected devices and high-performance analytics being enabled by 5G, make the energy operations very efficient and introduces high value added and low-cost services. 5G technologies enables a complex web of real-time interactions between the various elements of a smart grid, making the smart grid more efficient and flexible.

In case of faults or outages, protective functions in the smart grid network will be able to communicate with each other very quickly with very short latencies, leading to faster fault identification and restoration. This enables the networks to become **self-healing**. Utilities and other energy generators can build their own Virtual Networks functions, enabled by 5G network slicing features, so that they would be able to provide SLAs about technical performances and longevity of operations.

Summarizing, Utilities would have economic benefit in the following ways:

- Detecting energy theft/pilferage on near real-time basis and stopping it.
- Remote meter reading in real time, which reduces human resources, human errors, and time consumption for meter reads, thereby giving cost reduction in operations.
- Remote meter configurations, dynamic tariffs, power quality monitoring, load control, automated meter event data collection, on-demand billing reads/
- Ability to disconnect service remotely if bills not paid.
- Managing the load curve by introducing Time of Use (ToU)/Time of Day (ToD) tariff, demand response etc.
- Reducing equipment failure rates and maintenance costs. Remote detection of meter faults.
- Streamlining the billing process
- Improved grid stability and self-healing grid.
- Reduced capital and Operational cost
- Increased revenue
- Increased asset utilization
- Shift from carbon based to clean energy resulting in green economy
- Charging for EV

5G enables interruption free monitoring and controlling of mission-critical smart grid applications. The combination of IOT and Big data technologies allows the introduction of high added-value - possibly low-cost - services associated with energy efficient operations.

7.5.2.1 Opportunities for Aggregators or Virtual Power Plants

Distributed energy Resources (DER) like solar PV, wind farms, electric vehicles, energy storage etc are characterized by small capacities and connection to low & medium voltage electricity grids. There is new opportunity for power consumers to produce power for their own consumption and supply the extra generated to others users/ grid. There is going to be a significant increase in the number Prosumers with storage batteries. Prosumers may depend on the main electricity provider during periods when they are not able to generate energy from renewable sources and their energy storage has dried out. The service provided by the main electricity provider now will not only be limited to supply energy but will include balancing voltage and frequency support and ensuring power quality and reliability. The 'value of service' for the Prosumer changes from the net energy they consume from the grid, to the service reliability ensured by the grid.

The above scenario gives rise to a new class of service providers called "**aggregators"** or **'Virtual Power Plants'**, who can aggregate various distributed load, generation and storage of large number of consumers and prosumers. They can remotely monitor, control and manage the assets in real-time and optimize virtual despatching of distributed resources through data analytics. They provide the benefits to deliver peak load electricity on short notice. The flexibility allows the system to react better to fluctuations. The aggregator takes the specific requirements of all its clients and through advanced software ensure that these requirements are met. These virtual power plants create a coalition of heterogeneous DERs for the purpose of energy trading on the wholesale electricity markets by acting as an intermediary between DERs and the wholesale electricity market and trades the energy on behalf of DER owners who by themselves are unable to participate in the market. The combined power generation and power consumption of the networked prosumers can be traded on the energy exchange. By real-time data analytics, they can improve forecasting and trading of energies [15].

By optimizing the behind-the meter-assets, they will be able to capture value and monetize. They can ensure that the batteries of the Prosumers are charged when the wholesale prices are low. Prosumers can supply energy through the batteries when the wholesale prices are high. Monetizing the behind-the-meter assets is a good opportunity for start-ups who have domain knowledge of energy and have expertise in AI and ML to harness the value of the data [16].

The value of aggregators in power systems may be influenced by regulations. Fundamental value is derived from the act of aggregation itself through capitalizing on economies of scale and scope and by mitigating uncertainty. This is independent of the regulation and policy. Apart from this value, which is inherent to aggregation, temporary value could also be unlocked by aggregation by contributing to better power system functioning under present and near-future conditions. Regulators should encourage it and remove any obstacles for this. Regulatory deficiencies can sometimes create an opportunity for some aggregators to increase their personal value without enhancing the economic efficiency of the system. Regulations should be modified to ensure that this does not happen as it will lead to monopoly and restrict healthy competition [17].

7.5.2.2 Opportunities for ESCOs for demand response

Demand Side Management (DSM) aims to improve flexibility on the consumer side by improving energy efficiency that automatically responds to shifts in supply & demand. It can be implemented either through energy efficiency or Demand Response.

Demand response (DR) is a strategy used by electric utility companies to reduce or shift energy consumption from peak hours of the day when the demand and price for electricity is the greatest to leaner demand periods. It involves allowing customers to choose non-essential loads, which can be shed by the customers themselves or by the utility, at peak times. This may include turning off or dimming lighting banks, adjusting HVAS levels, shutting down non-critical manufacturing processes etc. On-site generation and storage can also be used to adjust the grid loads. These are temporary measures which are triggered by conditions like price fluctuations, power/frequency fluctuations etc and helps to maintain a reliable quality supply at optimal tariff. The advantages of DR are that allows businesses to avoid higher energy prices at peak demand times, creates additional revenue for prosumers when grid uses energy from prosumer, balances the grid, encourages businesses to increase energy use during period of peak renewable generation and gives clear understanding of the usage patterns to the consumer.

Demand responses addresses certain critical system needs such as to mitigate the effects of blackouts or brownouts during times when demand exceed supply, which usually occurs on extreme hot or cold days demanding more cooling or heating and on occasions where there are some public events in the area which creates a temporary great demand. Demand response is also used to support transmission reliability requirements that are imposed by regulators on utility companies.

Challenges in implementing DR may come from customer themselves, especially if they must curb heating/ cooling systems when temperatures are extreme and the need for them is the highest. Utilities must incentivize customers with special rebates/ discounts or variable pricing if they must get them to participate in this. Also, many customers may opt out of this as they may not be comfortable with the participation and this present challenges to reliability. ICT system implementation and integration into resource planning, may also be challenging. Utilities may introduce dynamic pricing schemes like peak time rebates, critical peak pricing and time of use rates to curtail usage during DR events.

DR technologies facilitate communications with customers and/or control heating and cooling systems. Utilities send signals to the participants of DR program using a variety of channels, including email, phone, and web portals. In-home or business display devices are another way that utilities can communicate with consumers about an event, including information about energy usage and pricing with smart grid. Consumers need to acknowledge their participation in the program. Home Area Network can be used to connect displays, load control devices and ultimately "smart appliances" seamlessly into the overall smart metering system. AMI is increasingly being used with demand response because it enables both utilities and end-users to have more robust data about loads, energy usage and electricity pricing. DR event is used by smart grids to enable utilities to detect and respond to load increases. Automating the DR processes would involve automatically detect the need to manage load, send signals to participants, and control all devices that use electricity within a home or business.

Traditional energy utility companies provide only energy to its customers, whereas an **energy service company** (**ESCO**) provides a broad range of energy solutions including auditing, redesigning, and implementation of energy systems projects, energy conservation, energy infrastructure outsourcing, power generation and energy supply. ESCO offers end users (prosumers) auxiliary energy services like insights, advanced energy analytics, automatic monitoring, and remote maintenance of energy assets.

ESCOs can play a significant role in the operation and optimisation of energy grids by using their energy management expertise and technological prowess to help reduce or shift their clients' energy usage during peak periods in response to time-based tariffs or other incentives. Also, they help in contributing to grid stability, safety and environmental sustainability while earning additional savings and/or new revenue streams for customers. ESCOs can take advantage of upcoming energy management platforms which enable them to participate in DR programmes without having to take an aggregator role. Apart from avoiding extra connections with aggregators, ESCOs can have access to a platform where all their buildings are managed at the same time. As an energy manager, they will be able to gather more controllable loads and provide more capacity to aggregators at once. In addition, they may have contracts with more than one aggregator just using one DR platform. The role as an ESCO is to save money for their clients and help them participate in DR in an attractive way to take their services beyond energy efficiency.

ESCO is responsible for performance and the value derived from the improved energy efficiency is shared by the customer and ESCO. The project risk is borne by ESCO, who must compensate the customer for non-performance on the RoI. Customer is assured of the energy and cost savings and is a good model to engage an ESCO, as the risk is borne by ESCO. Energy for heating, ventilation and air conditioning (HVAC) accounts for 45% of energy consumption in large buildings and this is the most significant for ECSO clients [18].

Frost & Sullivan estimates that the rise of smart cities will accelerate the adoption of DR solutions and this market is set to grow to $ 3.5 billion by 2025 in Europe. DR will especially thrive in the residential sector, electric vehicles (EVs), and data centre application segments. Their combined share is projected to increase from 5 percent in 2017 to 15 percent by 2025 [19]. Dexma has quoted that the global DR market will grow to $ 9.7 billion by 2023 [18].

7.5.2.3 Opportunity Value created by data in energy sharing

Sharing economies make use of high-speed information and communications technology (ICT) to match supply and demand and increase the use of otherwise underutilized assets through disruptive business models and horizontal peer-to-peer (P2P) trading. The development of smart grids and the widespread deployment of smart meters provide the essential infrastructure for the arrival of a sharing economy in the energy sector. A sharing economy can be one of the critical enablers that will unlock capacity in the existing supply network, deliver major financial value to renewable generation, and, ultimately, lead to affordable and clean energy for current and future energy customers.

Sharing energy systems happens when distributed resources are shared horizontally between energy producer and flexible users. Also, the utility company can lease some spare capacity to a third party, who then provides flexible network services that would match flexible generation and demand. This spare unused capacity is effectively utilized.

Big data and analytics are key enablers for introducing a sharing economy into a monopoly system. They can access and process large amounts of network, customer, market, socioeconomic, demographic, and environmental data. They can uncover hidden patterns, correlations, and insights into real-time information concerning the current state of energy producers, energy users, and the distribution system, as well as their likely future states. They will form essential inputs for decisions that can substantially increase operating efficiency and inform the most efficient energy transfer between energy producers and consumers, primary and secondary network operators, and network operators and network users.

A sharing economy mobilizes traditionally underutilized assets owned by individuals or communities and thereby enables them to provide services that create much greater value for the assets than would otherwise be available. The application of the principle of a sharing economy to local energy markets is through a P2P-traded market that allows a large number of fragmented energy buyers and sellers (prosumers) to find and trade with each other at a fraction of grid energy costs. Electricity prices would be set for an area or a transaction so that local demand can be matched to local generation and thus achieve a “local equilibrium.” This local equilibrium can absorb the uncertainty of the impact of low carbon supply and demand and thus reduce operational burdens on the DNO and the wider market. Intermittent renewable generating sources would be tracked in real time so that those with the lowest reliability would offer the lowest price, thus providing the greatest incentives for the demand side to respond [20].

Greater efficiency in electricity supply is achieved through managing flexibility in generation, demand and storage. For countries to transition to a low-carbon energy economy, it is important to achieve a higher utilization of system assets through use of high-speed ICT and creation of innovative P2P markets and business model innovation. Big data analytics plays the most significant part in deeper analysis of meter data along with weather conditions and socio-economic information. Predictive analytics can be performed with data from generation, network and customer assets to give good value returns.

7.5.2.4 Use cases in energy sector enabled by 5G

Remote monitoring of energy sites

- Monitoring energy production across solar farms, windfarms & power stations with smart sensors.
- Monitoring of health and readiness of the equipment to maintain operational efficiency
- Advance use of analytics and reports to reduce expensive service visits, and prevent outages

Smart meters for the smart homes

- Installing smart meters to efficiently manage, send and monitor data generated
- Maintaining precision in information, allowing frequent and more data to be sent and received
- Assisting users to analyse electricity consumption patterns across different devices

Distribution of energy within a smart grid

- Monitoring energy usage through connected services for improved efficiency
- Monitoring of energy consumption patterns
- Anticipating energy peaks to support load balancing
- Predictive analytics to assess outages

Smart Power generation, Green energy and distribution automation

- Smart power generation through 5G and IoT modernized transmission and distribution
- Generation of power with low carbon emissions, maximizing use of wind and solar power
- Balancing power generation systems during extreme wind variations and contingency situations

Energy efficiency and reducing the effects of climate change

- Smart and controlled lighting environment
- Reduced energy requirements monitored through wireless devices

7.6 Business Models

Incumbent large government owned utility companies may have to switch to their production to reduce carbon dioxide emissions and include renewable energy sources, which demands huge investments. The current electricity business model is based on subscription. This ensures stability for the utilities and the consumers. Utilities are guaranteed stable income and consumers are guaranteed electrical supplies at known costs. However, consumers had no choice regarding quality of service and reliability of supply.

The business model must support production and regulatory constraints on one side and customer demands on the other side. It must have provisions for providing various quality levels of electrical supply such as traditional supply, environmentally friendly supply, low-cost supply etc. It must have provisions for different levels of services like bundling pricing schemes, flexible pricing schemes, integrating net-metering data i.e the value of customer produced electricity, real-time peak pricing,

pricing for non-peak times, pay-as-you-go etc. The model should support additional services based on the data accumulated through smart metering and customer smart home applications. These services should support optimization of consumption, predictive maintenance, home surveillance, etc.

The advancement in the Energy and ICT sectors are giving opportunities for new business models based on shared economy. 5G technologies could enable new business models for smart grids. 5G features are expected to contribute to the smart grid new business model enablement.

The energy sector which hitherto had only incumbent, being large centralised utility company, will have to integrate and co-exist with new private energy producers entering the sector due to technology advancements and de-regulation. 5G enables a customer-centric smart energy ecosystem with a shared economy and gives rise to new innovative business models.

Energy providers cannot operate in isolation. New business models should look at the traditional utilities partnering with the services providers in the ecosystem with innovative revenue split schemes, incentive schemes, etc. The business model of Energy providers must include partnership with Telecom Operators and IT companies. The power utility sector is a long-term sector, and the devices are typically implemented for longer period say 12-15 years. The telecom solution implemented should be able to be supported for such long periods. Any obsolescence or changes in the telecom infrastructure could warrant upgrade or replacement of the smart grid devices, which is unwieldly. This could be contradictory to a typical Telecom Operator business model, as technological advancements would force them to revise their business modes in the short term. So, this is a challenge, and the Energy provider will have to innovate their business model along with the Telecom operator to ensure longevity of the installed telecom infrastructure.

Typically, a Telecom provider does not commit to SLAs for extended power outage conditions. However, in this case, they need to provide very quick fault localization and rectification. The business model should ensure stringent SLAs for minimal down time.

The business model should ensure cost stability of the telecommunication infrastructure over longer periods of time as Smart grids are implemented for long term. Now, telecom companies may not provide guaranteed infrastructure and costs for a long period as required for Smart grids. Hence, smart grid business model should take on ownership of the telecom network themselves. This can be done by the Energy Operator becoming a Virtual Network Operator themselves, by leasing a portion of the Telecom infrastructure and completely managing it themselves. This includes customer provisioning and management themselves. They must supply and provision SIM cards to be installed in the Energy devices and be responsible the operation and maintenance of the Telecom infra which they own. In this model, the network ownership and the spectrum remain under the control of Telco. 5G network slicing and Software Defined Networking helps in this.

Some governments are completely implementing dedicated telecom infrastructure for utilities. In this model, the energy provider builds, owns and operates their own dedicated network. There could be disadvantage in this as these dedicated networks would not be Standard based, and may result in technical and vendor lock-in. Telecom Operators also can utilize this opportunity to build a separate network for smart grids with re-designed network as lesser signalling is involved, as compared to a typical phone communication.

The Business model should give highest priority to security as the implications are disastrous for electrical supply. The Telecom provider should provide maximum security and precaution for infrastructure for a utility company like power.

With consumers becoming prosumers, utility companies may have to manage millions of small producers. This also leads to instability of production and usage and utility companies must plan for this. Large users of power, like large industries/ data centres etc, may opt to produce their power through renewable sources. Also, many companies may join and generate their own power and share it. This joint production may give rise to better and lower cost of production. They may develop their customised management systems to share the production costs and usage. Business models should account for efficient management of stored energy at micro-grid level.

One of the main drivers for Smart energy is the customer produced energy at their premises. The Capex involved in installing and operating Solar PV in customer premises could be expensive and prohibiting. New Energy business model could include **"Solar Power as a Service (SPaaS)"** model, where the Equipment provider could install all the required equipment at the Customer premises and charge the Consumer for the electricity utilized, which could be at a much lower rate than the one provided by the utilities. The equipment could be transferred permanently to the customer after certain period. This business model would be very well accepted by the Consumers as they do not have to invest and are able to get power at a lower rate.

Finally, security is of prime importance due to the mission critical requirements of the smart grid. The smart grid business model should ensure highest security level of the telecom infrastructure.

'Smart Energy' Business model

Author has defined 'Smart Energy" Business model based on the 7 Dimensions of Business Model [21].

Value Proposition –

- Near-zero outage, Minimal planned downtime during maintenance
- Reduced downtimes during outages through self-healing networks via smarter fault identification
- Enabling consumers to become prosumers
- Provide advanced, remote metering and lifecycle services
- Allow users to choose the energy source
- Provision for community grids for distributed energy
- Enabling green energy
- Streamlined, automated billing process

Customers or Users –

- Consumers and/or prosumers:
  - Homeowners
  - Factory operators
  - Building operators
- Power stations
- Energy services companies
- Aggregators or Virtual power plants

Value chain functions –

- Real-time power usage monitoring and analysis for ESCOs
- Remote monitoring of power stations, solar farms, wind farms
- Remote power usage monitoring and analysis for consumers/prosumers
- Energy redistribution among community grids to achieve local equilibria
- AI/ ML based data analytics
- Power supply pattern prediction for efficient load balancing

Competences –

- Technology awareness and implementation skills for smart grids
- Technology awareness among ESCOs and aggregators
- Users' ability to adapt to changes such as:
  - Time-of-Use and Time-of-Day pricing
  - Smart metering for power supply
  - Prosumer behaviour, to generate own energy for redistribution to the grid

- Advanced data analytics capabilities to capture trends among local grids and enable efficient redistribution of energy

Network –

- Telecom operators
- Prosumers, consumers
- Energy services companies (ESCOs)
- Aggregators or virtual power plants
- Smart metering solutions providers
- Solar panel manufacturers
- IT infrastructure companies and Data analytics developers

Value formula –

- Dynamic tariffs - Time-of-Use (ToU) / Time-of-Day (ToD) tariffs
- Normal usage tariff

Relations – The integrated IT platform that links the power stations, Energy services companies, aggregators, virtual power plants, local community grid operators, consumers and prosumers.

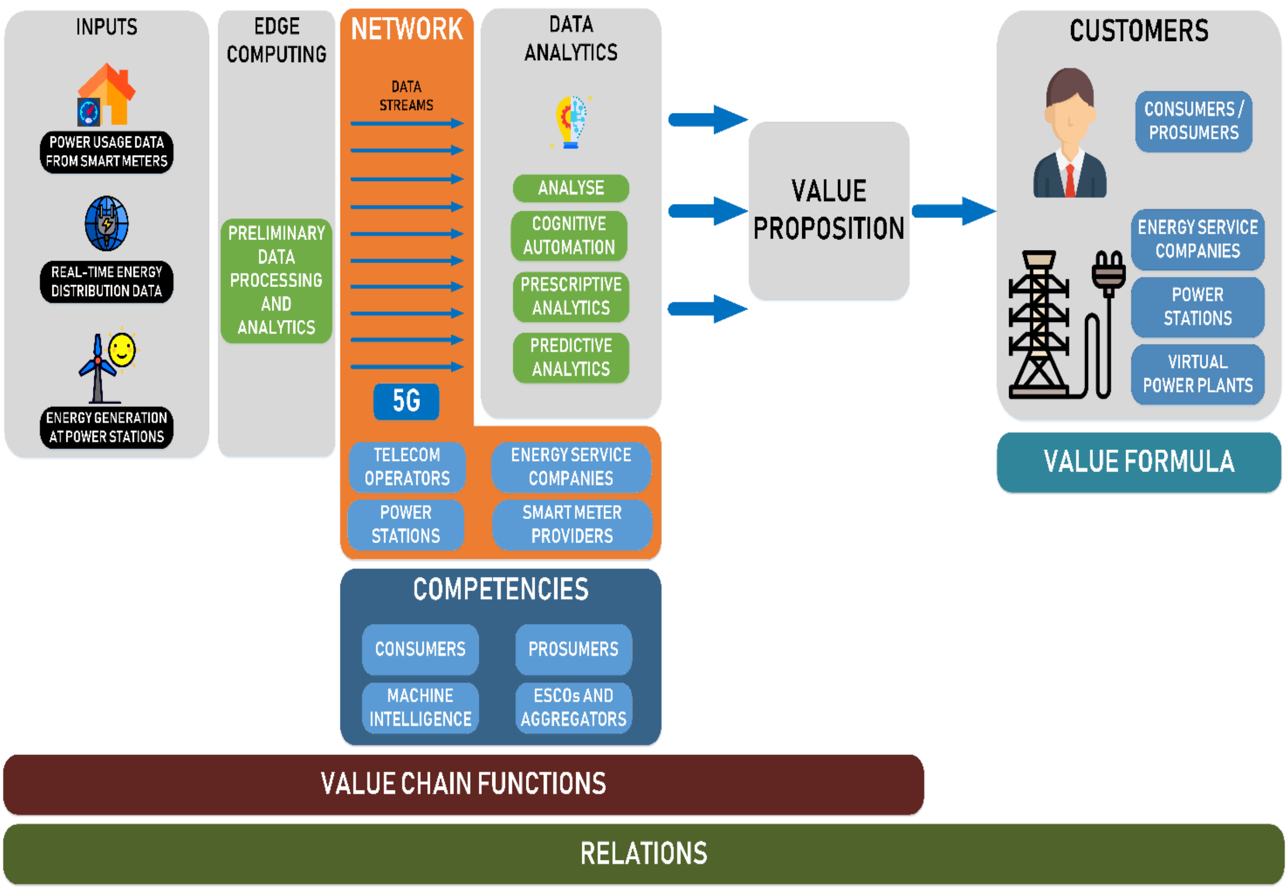

Figure 7.1: "Smart Energy" Business Model

7.7 Summary

Smart grid technology will support accurate, real-time analysis of power consumed and power outages. 5G would enable additional low-cost device connections, so that detailed coverage of the energy grid could be made possible. With 5G, very large number of unconnected energy devices can be monitored and controlled in real-time to allow accurate forecasting of power demands, by their integration into the grid. This could help in load balancing and probable reduction in energy cost to the houses. Outages can be quickly resolved reducing downtime.

IoT, Home Automation and Smart Cities enabled by 5G technologies will shift many of the centralized command and control towards a mix of central and distributed control structure, giving more power to the end consumer on the choice of energy consumption. This would enable the hitherto Consumer to become "Prosumer'. The earlier State-owned monopolies will have to work with multiple generators of energy.

5G features would contribute to smart grid 's new business model enablement. There could be opportunities for a new class of service providers called 'aggregators' or 'virtual power plants', who can aggregate various distributed load, generation and storage of large number of consumers and prosumers.

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8.0 Socio-Economic Impact of 5G on Education Sector

This section analyses the rapid technological advancements happening today and their disruption in the job market and subsequently the impact on education. The role of 5G in furthering the education and learning experience is analysed. Advances in mobile technology, IoT and Tactile Internet, can open a new chapter in education leading to Smart Education.

In this chapter, the global trends in Education sector is explored. The requirements of the learners and the education providers are analysed, leading to the demand drivers for Smart Education. The role of 5G in furthering the education and learning experience is discussed. The social and economic impact of smart education is analysed. Suitable business models for the education sector is presented.

8.1 Global Trends

Rapid technology growth enabling automation of tasks, is disrupting the job markets today and would lead to deeper impact on job market in future. Certain types of jobs could be completely wiped out, while certain other new type of jobs could be created. This would create a need of new types of skills, while making certain existing skills to become redundant. Also, it would make it extremely difficult and sometimes impossible to anticipate what skills would be needed for the next, say 10 years. So, designing a course curriculum for schools would be a big challenge knowing well that whatever is being taught now, would be useless when they come to the job market. Then, they may have to acquire new skills on the go. We are already seeing this happen. Even fresh Engineers coming out of colleges, are not able to get jobs as they were not taught what was required for them to get jobs. Also, people having jobs today will have to constantly upskill or re-skill to remain relevant.

According to World Economic Forum report [1], 65% of children entering primary school today will ultimately end up working in completely new job types that do not yet exist. Also, the global workforce would be impacted, and more than 5.1 million jobs would be lost to disruptive labour market changes over the period 2015-2020, with a total loss of 7.1 million jobs. 2/3rds of these are routine white collared jobs such as office and admin roles and manufacturing roles. The gain will be 2 million jobs in computer, mathematical, architectural, and engineering jobs. Two types of jobs will increase -Data analysts and Sales reps which require negotiating skills.

Younger generation are hooked on to electronic gadgets and schools are changing the learning delivery by using them. There is growing interest in using Virtual Reality and Augmented Reality based teaching in education, as a means of improving the learning process.

According to a US wide survey of more than 1000 US K-12 teachers done by ISTE, it was found that a greater percentage of teachers were interested in using VR as part of learning experience, but only very few are using it currently. The survey reported that [2]

- 86% feel it is a challenge to keep students engaged in curriculum.
- 93% feel that their students will be excited to use VR
- 83% say that VR might help improve learning outcomes
- More than two-thirds (68 percent) of teachers say they want to use virtual reality to supplement course curriculum to help students better understand course concepts,
- 7 out of 10 teachers (72 percent) want to simulate experiences relevant to course content,
- 69 percent say they would use virtual reality to travel to distant world landmarks
- 68 percent want to use virtual reality to explore otherwise inaccessible locations
- 42 percent of high school teachers (grades 9-12) would like to use virtual reality to tour college campuses to encourage students to pursue higher education

A survey conducted in China [3], reported that VR-based education offers advantages in boosting learning and retention versus traditional classroom education. VR-based education was shown to improve student test scores and knowledge retention compared with traditional classroom education. Below average students in pre-study test, performed much better after undergoing a VR based curriculum.

The proliferation of AR/ VR tools is expected to rise in many sectors, and Education sector could use this effectively. ABI Research estimates the total AR market will reach $100 billion by 2020 with an estimated CAGR of 73% from 2015 to 2020 which includes AR hardware, AR Content, and software. AR Smart glasses are forecast to ship 21 million units in 2020 with a CAGR of 78% from 2015 to 2020 [4].
Massive Open Online Courses (MOOC) have become very popular and this enabled by connectivity would become the norm.

Developing countries have large population entering the job markets. According to Economic Survey 2014, India has high working population constituting 58% of population in 2001, which is expected to increase to 64% by 2021, with a large number of young persons in the 20-35 age group. Most of the above are in rural areas [5].

Digital natives have grown up in a world of computers, mobile phones & internet – experiences that have shaped, and continue to shape, their behaviour. Their population as a percentage of the global population is bound to increase. Choices for the Student will be plenty, and they need to make the right choices for what and how they learn.

8.2 Demand Drivers

8.2.1 Consumer Drivers

Here, the Consumer is the Student or the Learner, i.e a person who needs education.

Education till now, have focussed on students becoming able to remember lot of things and some amount of logical reasoning. There has been no attempt to develop students' curiosity in learning, cognitive skills, and human skills. This is the problem in today's education system. Not all people are good at remembering large amount of information or good at logical reasoning. These huge amounts of learning which needs to be remembered and logical reasoning, will get automated with help of technology. Humans are good at social and emotional skills leading to perform better in non-routine tasks like sales negotiations and imaginative task. They have the power of natural curiosity which gives rise to creative in solving unstructured problems. So, our education systems should concentrate in developing these skills, so that learners will develop curiosity to learning and will find ways to achieve that. Learning process must be more fun and interesting and should develop a sense of curiosity amongst learners.

Students want flexibility in education. They want to be able to choose their course of choice from global players at their place of convenience and time. Distance should not become a hindrance to learning. So, the education system should allow distance learning. Students should be able to access their learning content wherever they are and at any time, and through any device. Need based education will be required i.e. when a need for a particular topic arises, people would want to learn that immediately so that they are able to apply it in real life. So, Just-in-time micro learning is required and this needs to be personalised. Learners, be them school students or professionals, need to be able to access more data and information than ever before.

Students with disabilities will need ease of accessing education. They need education to be delivered at their convenience place and time as they may not be able to travel. Students motivation are driven if the education is personalised and contextualised connecting it to everyday experience, which reinforce learning as it shows the practical application of it. Virtual representations of the objects to be learned to enable interactions with the models. Gaming of learning would make it more interesting.

Majority of parents would want to be able to transparently follow, and be involved in, the learning process of their children, specially K12.

Therefore, it is required to extend our experience of learning and teaching far beyond what we have had over last decades.

8.2.2 Business Drivers

Here, the Business is the Education Provider. In a rapidly changing employment landscape, it is important to anticipate the future skill requirements and constantly update the education content and delivery. The education is not only addressed to young students, but also to working professionals to constantly upgrade their skills to stay relevant in the continually evolving job market which is impacted by Industries 4.0. Education does not stop at Universities. It is continual learning and Organisations must constantly upskill their employees. Skill and talent development are mission-critical priorities for organisations, to boost employee productivity. Organisations should become "Learning organisations" and should provide adequate learning opportunities for employees. This also helps in employee retention. Organisations should become talent incubators. Learning to be aligned to business priorities. It must be on-going and part of work. It should generate a sense of curiosity to the employees, so that they will take it forward on their own. The future of learning is analytics driven, so that it can become personalised.

It is required to have campus connectivity and classrooms which are digitally connected to each other and campus, to get real time feedback on the lectures. Also. There are huge numbers of connected devices assets in a campus and needs a system for tracking these assets.

Students will be using a wide variety of electronic gadgets. These devices need to be plug and play and self-organising. System should allow real time interaction with the environment. System should provide very high throughout as students are heavy users using audio-visual communication.

There are diverse set of applications in education, each having different latency and throughout requirements. Some applications which needs tactile interaction through internet would need very low latency, while some other applications may not have a need for low latency. System should support all types. Also, there are different projects and departments in campuses having different levels of requirements w.r.t latency, bandwidth, reliability etc and they may need to be independent of each other. Isolation is required between them and it is required to create separate networks for these.

Tele teaching and tele-mentoring will be needed to be offered. This requires a network capable of transforming teacher's tactile communication through internet wherein to have natural interaction of hands with video and audio feedback. System implemented should allow a virtual presence of students in the classroom. Virtual Reality and Augmented Reality needs to be used in education to create immersive, simulated training and education platforms. This should enable learners to experience the materials as if they are in the room, regardless of their location. They should be able to participate in virtual field trips exploring far away destinations, without leaving their classroom. Interactive 6 degrees of freedom video to enable the student to move around within the recorded video, requires very bit rate compared to 4K video. These video formats will be much more data intensive. The requirements for implementing Augmented Reality and Virtual Reality Services are optimised routing, seamless wide-area coverage, virtual presence, low delay speech & video coding [6]. The above requirements would demand exponential increase in data processing, very high bandwidth, both download and upload, and a very low latency in order of few milliseconds.

8.3 Technology enablers

5G characteristics that will enable the demands for a sophisticated education delivery system are:

- Bandwidth and data rates: needed to support both uplink and download of video rich services over wireless networks.
- Ultra-low latency: for enhanced user experiences potentially including the delivery of 3D images required for education purpose.
- Always on connectivity:
- 5Gnetworks offers the data rates and capacity needed to support video rich services over wireless networks.

Latency of < 1mS enables tactile internet leading to tele teaching. 5G, with its capacity to connect local networks and the big Internet, can provide a strong support to the future of education. This connectivity space, involving both local and global networks, is what can make a difference in education between 5G and current systems. The smartphone, in perspective, besides being a data presentation/visualization system is a connection gateway and can become a hub for aggregating personal knowledge and for customising external knowledge, integrating them and letting the education process leveraging on them. the transition of our smartphones to 5G will be much quicker and this will enable their use in a "5G way" to access services on local networks in parallel to the access to the global network based on 3G and 4G. This smooth scaling up, transitioning, from present communications systems to 5G can be exploited in the education domain.

Currently, VR technologies supported on 4G and Wi-Fi networks, is not effective as the latency between the image seen and movements of the wearer can result in confusion and problems. These problems and the sheer amount of data that must be transmitted to operate an entire classroom of VR devices has prevented VR from being fully adopted as an educational resource. 5G will allow VR and AR technology to reach their full potential. The super low latency speeds associated with 5G networks will eliminate 'cyber sickness' while also being capable of supporting a huge number of connected devices across a concentrated area.

The use of Network Slicing in 5G can help to meet the need of different project/services through having totally independent and isolated virtual networks within or between an individual physical infrastructure, making it possible to provide different level of latency, reliability, availability and security for each use case.

5G with its 20 Gbps peak data in indoors and dense areas, as well as several 100 Mbps everywhere can meet the throughput requirements as demanded by the heavy usage by students. 5G features supporting both crucial latency requirements and relaxed latency requirements, supports the need for supporting diverse applications in education. 5G support of IoT, enables asset tracking and management. 5G will education institutions better integrate AR, VR, AI and IoT into teaching and learning.

8.4 Socio Economic Impact

Developments in mobile access technologies have provided the possibility of having higher availability of the rich digital resources beyond the physical confines of the classroom and in the hands of learners. New mobile technology and connected devices will give students the opportunity to learn with minimal intervention from teachers and mostly through exploration, discovery, and peer coaching.

5G has the potential to revolutionise the future of education. The transition from current communication networks to 5G can be exploited in education with increased remote access to multimedia learning. It disrupts the traditional way of education by enabling learning anytime at anyplace. It may no longer be only classroom-based system. Teaching will need to adapt to both the physical and virtual classroom. The teacher’s role will change to be a coach and guide.

Education provider will have to develop eLearning modules for all offered courses, so that course delivery can be made with blended classroom and remote classes. eLearning should be available on smartphones/ tablets and should provide interactive learning. It will enable creation of Virtual classrooms with augmented reality features. This should be enabled with cameras on remote student’s computers or smartphones/ Tablets. Student should be able to interact with teachers in real time. Constraint of physical classrooms will be removed, and learning will become virtual with technology enabling Virtual and Augmented reality features. Applications such as Virtual Reality (VR) and Augmented Reality (AR) will play a big role in quality education and understanding-based learning. By combining Tactile Internet with VR and AR the learning experience will go far beyond today’s one, bringing new definition to Tele-teaching, Tele-mentoring, virtual university, virtual classroom, virtual team-working, etc.

Education experience will be enhanced by Virtual Reality. This will improve understanding-based learning among students. These services can be customized for education by introducing possibility of interaction with the learning object, making the learning process more fun and interesting. VR can create virtual presence of the students in a classroom, even if they are far.

Education experience will be enhanced by Augmented Reality. Immersive AR can enable new ways of learning and team working in education through services such as mobile cloud classroom and Virtual Presence. Teachers can get necessary information about each student and be aware of their specific needs and capabilities for a more personalised teaching. Students/ learners can participate in virtual field trips without leaving their place. Virtual cockpits can be used to train pilots. In fields such as aviation and medicine, where training is both costly and risky to the learner and others, VR/AR delivered learning methods offer both a cheaper and safer alternative. Virtual Reality has the potential to completely transform the way in which we access education from the city to our most remote locations. VR allows for the sharing of knowledge regardless of physical distance, bringing us one step closer to becoming a truly global society – a society in which information is freely shared and people of all walks of life can learn from each other, no longer limited by their circumstances. Immersive VR based games review system, can give better insights into the game being played.

Tactile internet produces new experience in distance learning and remote teamwork for manual training and skill development. Combination of this with VR, could produce great education experience, as it can also give hands-on experience for remote students of laboratory equipment's and facilities. This enables **tele teaching and tele mentoring**.

The impact that VR will create in learning are:

- VR can enable experiential learning by simulating real-world environments. Students can test their skills, record their work, and interact with experts all within VR.
- For visual learners and for those with learning challenges, VR provides an alternative medium to meet their needs.
- There will be increased engagement levels and improved test scores with VR based education programs as hands-on learning with VR would increase cognitive memory.
- VR can bring learning to life via a virtual environment, with connecting to the subject matter makes it easier to understand the remember the subject matter. Eg: Medical students performing an operation with VR. etc

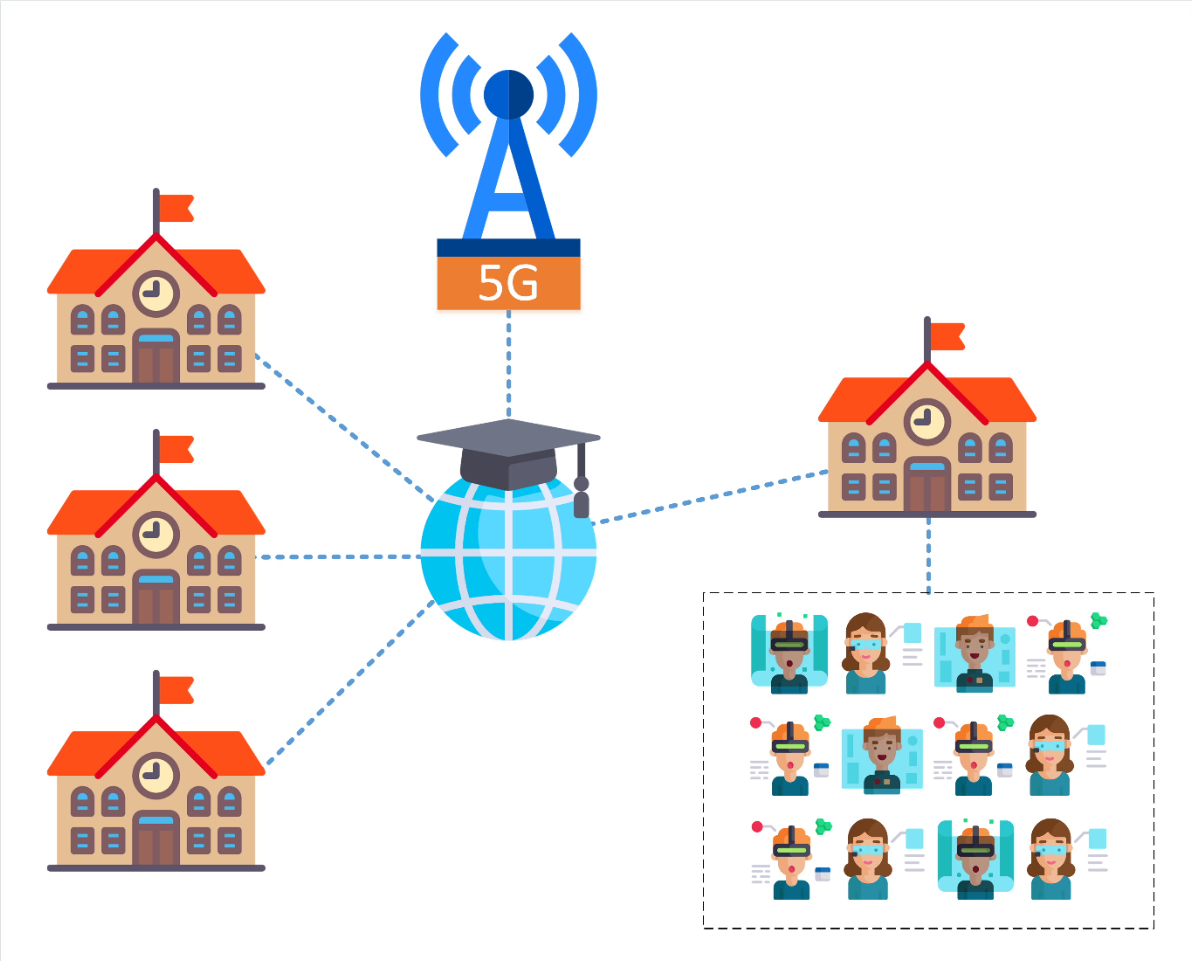

FIGURE 8.1: Smart connected education with AR/VR based learning enabled by 5G

Figure 8.1 above depicts smart connected education with AR/VR based learning.

Few examples of Companies which are using VR for education

- Walmart is using VR to help train its employees on topics like management and customer services.
- EON Reality has collaborated with Oral Roberts University to create global learning centre.

A particularly important impact is that it would enable **personalised learning for students**. As all students are connected to system, the system can analyse each student's learning pattern by capturing their learning experience and creating different groups of students based on their comprehension of the subject and can deliver customised offerings to these students. Every student's learning content could be stored in cloud, and they have just access it through their device and access their personal content. They can continue their work at a suitable time and place through any other device and still get immediate response. At home, they could be working on their desktop. When they travel, they could resume working on their mobile. Work is uninterrupted and this is enabled by excellent connectivity. IoT implementation enabled by 5G in campus can facilitate Connected classrooms and connected campus.

5G enables mobile education gaming and makes games accessible to children through cloud storage, which makes learning interesting. A gaming app provider Rooplay is developing this along with Ericsson [7]. VR and AR are an opportunity to finally connect with both learners and teachers in a novel and meaningful way. Advances in mobile technology like 5G, IoT and Tactile Internet, can open a new chapter in education. Teacher's role will change to be a guide and coach and they will need to adapt to both physical and virtual classrooms. Massive Open Online Courses will become common and will offered by reputed institutions.

8.4.1 Additional opportunities / value creation in education sector enabled by 5G

Value creation plays an important role in the strategic decision of education providers. They must find out ways and models on enhancing value creation. Here the value creation is different from a business where earned profits could denote value. Education institutions do not create value against money earned, but value is created by research patents, research publications, start-ups incubated, new technology produced, technology used in education delivery etc. Value creation also depends upon the nature of the education institution, whether they are publicly or privately funded [8]. In some countries, like India, value of an education institution could also be determined by the percentage of students who gets selected in campus interviews by top paying international companies and also on the highest starting salary obtained by passing out students. Employability of students becomes a significant factor here. The above factors of value creation are dependent on new innovative methods of education delivery adopted by the institutions.

Business opportunities are created by the new demands in the education sector [9]. Market size of education is growing exponentially. Many countries have made education as a universal right. For example – Indian Government's "Right to education" act. Motivation for learning and formal education is not only due to means of earning livelihood but also due to earning respect and status in society. Continual education is now required for adults and working professionals also, to remain relevant in job and society, as reskilling/ upskilling is required due technology obsolescence. Job specific training is becoming significant by corporates and industries. Regulatory compliance also calls for mandatory training and certification. Globalization means mobility and the need to learn new languages [9].
New business opportunities include:

- Digitization of knowledge, content, experience, and the skills can be monetized by delivering it on-line to large number of remotely dispersed students in an interactive manner.
- Virtual Reality based education – Learning process is made more fun, interesting and interactive by using VR in learning. Examples could include virtual tours of human body and interacting with

models etc. It can enable virtual presence of remotely located students bringing in new experiences in distance learning.

- Smart campuses and classrooms – IoT applications enabled by 5G connectivity can create smart classrooms and campuses, which could automate the administrative process and give more time for student's knowledge development. Examples could include automatic registration of the student in the class/campus, real-time analysis of students work and feedback thereof etc [10].
- Virtual classroom– Physical location will not be a barrier to learning as the combination of VR and tactile internet can enable sharing of resources between large group pf students wherever they are located. This could provide hands-on experience with education facilities and tools despite not being physically present there.
- Customized interactive education can be provided to suit every student's style and pace of learning
- Personal assistant robots for physically challenged students, can help them in interaction with the education system and its environment.
- Students can have only device to access personal and study content from anywhere through distributed cloud and multi-access edge computing. This will reduce the number of books they have to carry and eliminate the burden of carrying heavy schoolbags as it is currently done.
- eLearning content on extras special subjects could be charged by 'pay per course' or 'pay per hour' basis, bringing in additional revenue to education institutions.
- Anytime -anywhere" on-demand learning would become feasible. Students can learn at their own pace comfortably
- By digitally keeping track of the lesson delivery and students' progress, teachers will be able to evaluate the needs of the students in a better way and the educational institutions can also be able to evaluate the effectiveness of the teaching staff more accurately.
- New topics pertaining to the course can be delivered as and when available to help students stay updated and working professionals stay relevant and the progress can be tracked.
- Use of WiFi networks in classrooms in remote areas [11].
- WiFi enabled school buses, connected by 5G, can ensure that students are connected even while they are in transit.

Higher education will move away from isolated campuses to integrated working and learning models. Their role will be that of a facilitator and enabler to the students learning experience [12].

A survey conducted in China [3], reported that VR-based education offers advantages in boosting learning and retention versus traditional classroom education. VR-based education was shown to improve student test scores and knowledge retention compared with traditional classroom education

An entirely online tertiary education platform called Open Universities, is used in Australia by higher education universities to offer online courses as part of distant education. AR and VR are used enhance

educational experiences of all learners. It is reported that 80% of information presented via VR is retained by students compared to 20% when physically listening to a lecture. Currently, these technologies were supported by 4G and the latency between image seen and movements of the students resulted in a bad side-effect. This along with the huge amount of data required to transmitted to operate a entire classroom, made it difficult to VR to be really adopted foe the education purposes. However, the low latency and ability to support large number of connected devices through 5G, can make VR an extremely attractive solution to provide the virtual learning experience [13]
According to the IHS, in 2016, the 5G-enabled output from the education sector was $277M, and that will only increase over the years, as 5G asserts its presence as a technology enabler [14].

8.4.2 Barriers/constraints to virtual classroom learning and steps to overcome them

Virtual classrooms need technology to implement. 5G connectivity and AR/VR technology provides the required technology. However, there are other barriers and constraints which needs to be overcome to make it successful.

8.4.2.1 Barriers and constraints to virtual classroom learning

- Content delivered remotely cannot be the same as in live classrooms. In live classrooms, the teacher is interacting directly with the students and can engage with students on eye contact and body language. They can watch the entire class at a time, understand and manage the group dynamics and can modulate their teaching by using different voice techniques like tone, volume and pace. By this, they can ensure that the learning is happening, and the teaching objectives are met. Teacher in a classroom can understand how to facilitate a conversation or activity and adjust course direction, as necessary. This may not be possible when the same is delivered to large number of remotely dispersed students simultaneously.
- Content designed for live classrooms may not be appropriate for virtual classrooms. Usually some subject matter experts design the content, without having any experience in designing or facilitating virtual learning.
- All the learners in a virtual classroom, who would be in different remote locations, may not have the same technology tools and communication bandwidth.
- There would be cultural barriers as it involves global audience. The content and the delivery language which would have been successful in one culture, may not work in some other culture. Language and accents also are constraints when it comes to virtual teaching
- In a physical classroom, the teacher can have flexibility in time to ensure that the students have got all their doubts cleared. This may be difficult in virtual classroom, as the delivery is time bound.

8.4.2.2 Overcoming the barriers and constraints

- Content for virtual classrooms must be redesigned. This should have content which can create impact on the distant learner and keep them engaged. Content should be designed with more graphics to make language less of a barrier.
- Instructors must be reskilled to understand the problems of virtual classrooms and the learning environment. They themselves must undergo virtual classroom training, where they get the real-feel experience, which would help to fine-tune their content.
- Program facilitators must be skilled to overcome technology barriers. They need to learn how to rely on other senses and inputs, since they are no longer able to see participants. They also need to learn how to work with different communication options available to learners within the virtual classroom. These could be chat, whiteboard, and feedback tools to encourage interaction and collaboration. All communication should be equivalent to speaking aloud.
- Facilitators should be trained to seek out subtle signals that indicate the level of participant engagement and knowledge transfer. In the virtual classroom, cues may come from unexpected sources, and can be uncovered by paying attention to response time, response quality, side conversation, etc.
- To successfully handle global audience, the virtual facilitator must develop culture competency i.e they need to identify how their own culture interacts with other cultures. They should recognize the influence culture plays in the virtual classroom and adjust their existing facilitation skills to accommodate a global audience.
- As facilitators become more competent in managing technologies and activities, they need to learn to manage their time more effectively, as well.

8.5 Business Models

Changes to the business models of companies are happening at a disruptive pace in the employment sector over the coming years and will have a significant impact on jobs, either by new job creation or job displacement and may lead to widening skill gaps. This will necessitate business models of education institutions to be changed and become innovative.

The future learning model will be an international, immediate, virtual, and interactive environment which enables learners to learn and interact in much different ways that we do today. The new model will be learner-centric, skill-centric, on-demand and personalised. The model will have to improve student development in the areas of critical-thinking and collaborative learning and thinking in long terms is important.

Large Universities and Institutions will have to change their current 'large area campus' model to 'agile digital delivery' model. The model would be dependent on connectivity and network-based solutions and the Institutions need to partner with IT ad Telecom companies for networking and connectivity solutions and for the digital content development. The model will have a follow a data-driven approach to learning. Data must be used to help students know what they should learn, reducing barriers to interacting regularly and teach in the context of how it will impact the student. This should enable "Personalised" approach to students with the understanding that every student is unique and needs a customised approach to their development. The Model should arouse a sense of curiosity to students to provide tools to enable them to take their studies further on a given topic.

Universities and Education Institutions can no longer operate as a stand-alone entity and will have to collaborate with global Institutions for offering specialized niche courses. They will have to adapt to a Partnership model with global universities, so that they can offer collaborative course and include MOOC in their offerings.

'Smart Education' Business model

The author has defined the 'Smart Education" Business model based on the Seven Dimensions of Business Model [15].

Value Proposition –

- Enable distance education
- Creating an engaging learning environment for students
- Real-time remote tutoring, both personalised and MOOCs
- Enable need-based and personalised micro learning
- Provide gamified learning experience

- Provide AR/VR based learning for stronger understanding of complex concepts that cannot be captured on a chalk board
- Create virtual university and virtual classroom experiences
- Conduct personalised tests and exams for students remotely, at a time and place of their convenience
- Improve employability of students and make them industry-ready

Customers or Users –

- Students
- IT professionals looking to upskill or reskill themselves
- Teachers / Instructors
- Educational institutions and Program facilitators

Value chain functions –

- Digitisation of courses
- Learner-centric, skill-centric, on-demand, personalised delivery of courses
- Provisioning and operation of virtual classrooms and distance learning courses
- Delivering gamified and AR/VR based courses
- Conduct remote examinations in real-time, with automated monitoring to prevent malpractice
- AI/ ML based data analytics
- Personalised course suggestion based on interests and market trends

Competencies –

- Technology awareness and implementation skills for smart education systems
- Students' ability to adapt to changes such as:
    - Online learning , Remote learning
    - Peer-to-peer learning
    - Gamified learning
    - AR/VR based learning
- Instructors' ability to adapt to changes such as:
    - Virtual classrooms
    - Provide personalised guidance and coaching to students
- Educational institutions' ability to adapt to changes such as:
    - Virtual classrooms
    - Virtual campuses
    - Infrastructural requirements for distance learning, virtual classrooms, gamification of courses, AR/VR based delivery of lessons
    - Collaborative course offerings with other universities

- Program facilitators must be reskilled to overcome technological barriers
- Advanced data analytics capabilities to assist personalised learning

Network –

- Telecom operators
- Educational institutions
- Gamification service providers
- AR/VR infrastructure and service providers
- IT infrastructure companies & Data analytics developers

Value formula –

- Annual or biannual fees, as currently implemented by most educational institutions
- Pay-per-Course tariffs for online eLearning courses
- Pay-per-Hour tariffs for one-on-one physical and remote tutoring
- Effort-based tariffs charged on the learner based on the effort required to teach them a concept, to incentivise better understanding of concepts

Relations – The integrated IT platform that links the educational institutions, online MOOC providers, gamification service providers, AR/VR service providers, instructors, IT professionals and students.

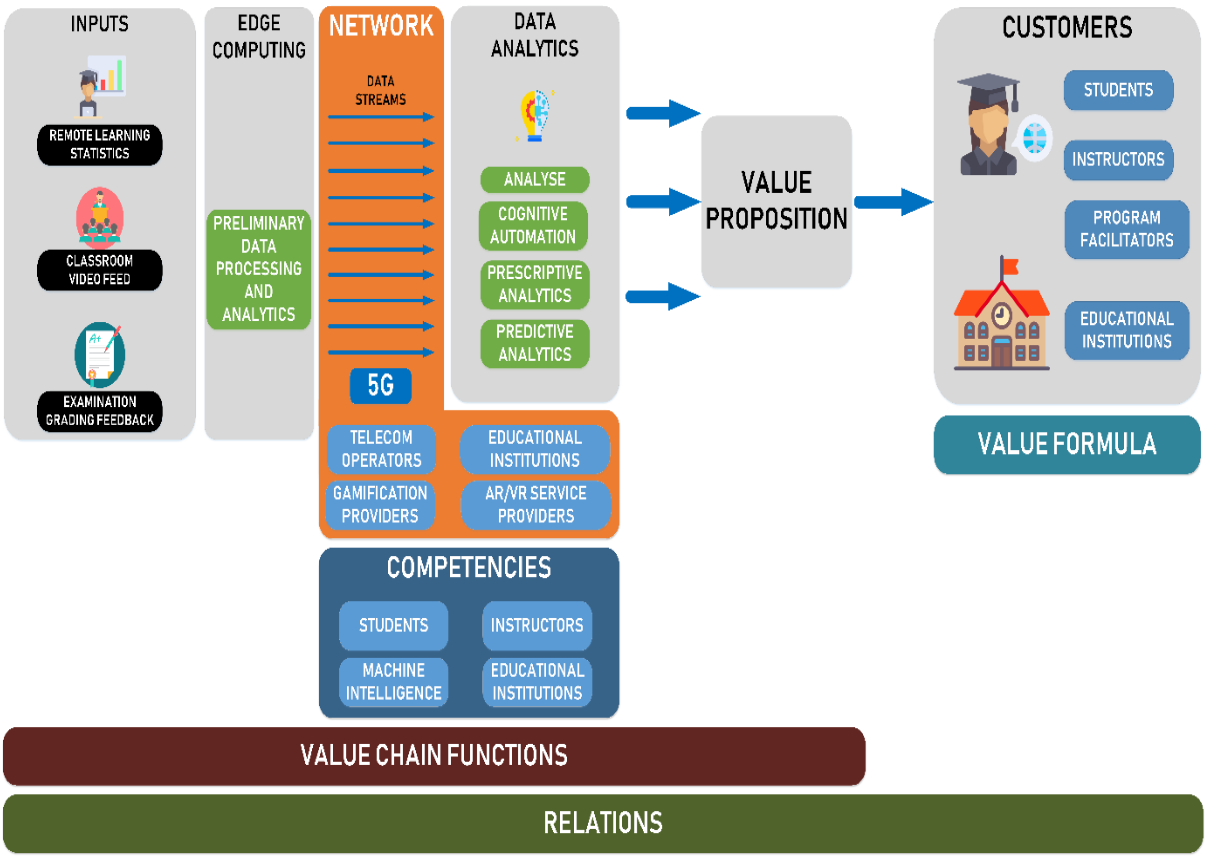

Figure 8.2: “Smart Education” Business Model

8.6 Summary

Education sector would be revolutionised by 5G. The transition from current communication networks to 5G can be exploited in education with increased remote access to multimedia learning, disrupting the traditional way of education by enabling learning anytime at anyplace. It may no longer be only classroom-based system and will enable creation of virtual classrooms with augmented reality features. Teaching will need to adapt to both the physical and virtual classroom. This will bring new definition to Tele-teaching, Tele-mentoring, Virtual university, Virtual classroom, Virtual team-working, etc

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9.0 Socio-Economic Impact of 5G on Service Providers, Enterprises and Businesses

5G will have a great impact on different Service Providers like Smart Home Providers, Safety and Surveillance service providers, Content Service Providers, Enterprises, Retail Business and M2M/ IoT System Integrators.

In this chapter, the global trends in the above domains are explored. The consumer and the business drivers in each segment, are analysed. The features of 5G that enable these requirements, are discussed. The social and economic impact in these domains are analysed. Suitable business models are presented.

9.1 Smart Homes Providers

9.1.1 Introduction

A Smart Home addresses the needs of its owners like enhanced comfort, security, convenience, energy efficiency, entertainment etc, through intelligent devices and enhanced connectivity. The needs could include provision of security and surveillance by remote monitoring of premises, ease of home appliances remote control, ensuring safety of young and elderly house members etc. The connectivity of the various devices and appliances and ability to remotely control them to the benefits of the homeowner, makes the home smart. Advanced sensing and control are basic features of smart homes. Functions to be controlled may include home perimeter security and interior security, temperature, lighting etc. They should offer the ability of remote control though a smart phone or a smart device.
The smart home should enhance intelligent living.

9.1.2 Global Trends

The trend is that a home would be full of connected devices, not only providing information on their environment but also communicating with each other. Homes are expected to become massive sources of information and will generate large amount of data. Mobile phone will emerge as the preferred medium of entertainment over TV, Movies, Radio & newspaper.

Smart TVs, Smart Gateways, Games Consoles and even tablets would vie to be the main hub for delivery of entertainment content in the home. Ultra HD TVs will have become mainstream with hundreds of Pay UHD channels being available in addition to plentiful streaming UHD services.

Homes will have a multitude of 'TV screens' and seamless transferring of content between those screens will have become a mainstream activity. Mobile TV will dominate as it provides enhanced personal viewing experience anytime-anywhere access

More and more home devices and appliances are becoming IoT controlled. Gartner research has predicted that the spending on connected home devices will total $ 189 million in 2018, an 18% increase from 2017 [1].

There is emergence of Virtual Personal Assistants, like Amazon's Echo and Google's Home, which enables users to control the connected home appliances through these personal assistants.
The forecasted market size of global smart home market in 2020 is USD 40.9 Billion growing to USD 53.45 Billion by 2022 [2]. Understanding of Smart homes and their need is mainly amongst upper end homes in metros.

9.1.3 Demand Drivers

Major drivers for Smart homes are Safety & Security, Convenience, Energy efficiency, Entertainment and immersive real-life experience in events and relations. Safety & Security are the primary drivers. Remote control of electrical controls and gadgets provides convenience and are desirable features. Entertainment related features are those that delight the consumer.

Consumers need to monitor their home from anyplace and anytime. Home video access and surveillance for security purposes is very essential and they should work in real time. They need to ensure that energy is optimally used in the homes and there should be intelligent management of energy. All electrical home appliances should be connected and be available for remote monitoring and control. Home appliances will come with embedded SIMS and high-speed connectivity and fast response times are needed. Home automation providers need excellent connectivity at very speeds and low latency networks.

Consumers need rich video services for entertainment. They want to be able to access exclusive content on demand. Expectation is for instant download and play of a full-length film. Consumption of content by the home user is exponentially increasing. Consumers want immersive experience in television viewing. They want to enjoy TV shows as if they are actually in the event. They want to enjoy new places around the world by virtually being there. They want to keep in touch with friends or relatives wherever they are in the world, as they are sitting in front of them and talking to them. The hindrance of distance should be removed. They want to play on-line games by connecting with remote players in real-time.

AR and VR would become standard for gaming and video programming. This will necessitate faster connections. The connectivity should enable high-speed, next generation gaming and video platforms, which requires vast amounts of data and ultra-fat processing speeds. Service providers' requirements are that they should be part of the rising trend of connecting people's homes and lives. Another desirable requirement is that music, lighting, temperature etc in the room should be dependent on the person's "mood".

9.1.4 Technology Enabler

5G characteristics that will enable the demands for sophisticated home automation systems are:

- Bandwidth and data rates: needed to support both uplink and download of video rich services over wireless networks.
- Ultra-low latency: for enhanced user experiences potentially including the delivery of 3D images and holograms.
- Always on connectivity

Important requirements for Smart Homes met by 5G are video for security and surveillance and AR VR applications. 5G will transform the home viewing into a much more immersive experience. 5G ultrafast broadband and ultra-low latency, coupled with VR Headsets, will enable home users to be able to plug into immersive, life changing experiences. 5G ultra-broadband supports higher bandwidth capabilities and provides ultra-low latency to ensure networks can cope with extra demand of exponentially increasing consumer content.

5G networks offers the data rates and capacity needed to support video rich services over wireless networks. 5G will enable vast increases in IoT to support connecting all your smart home devices.
5G can enable multiple secure connections at the same time. So, there could be one home connection for family to access, another one for a separate utility connection for companies – enabling the water company to measure usage. 5G also provides the secure environments to enable telehealth and monitoring in the home.

5G Technology provides flexible, programmable networks to deliver seemingly infinite capacity to accommodate varying traffic demands. They are built on common platforms that adapt to any cloud-advanced applications. And they offer advanced analytics to control and manage the entire network, with end-to-end security built in.

9.1.5 Socio Economic Impact

The elements that automate the functions of a home are connected to each other controlled by a gadget placed inside the home (that may be called as home gateway). This connectivity could enable us to take centralized decisions and monitoring and would make the home autonomous. These systems, even if individually smart, do not make a complete smart home. This scenario has been projected in Figure 9.1 below.

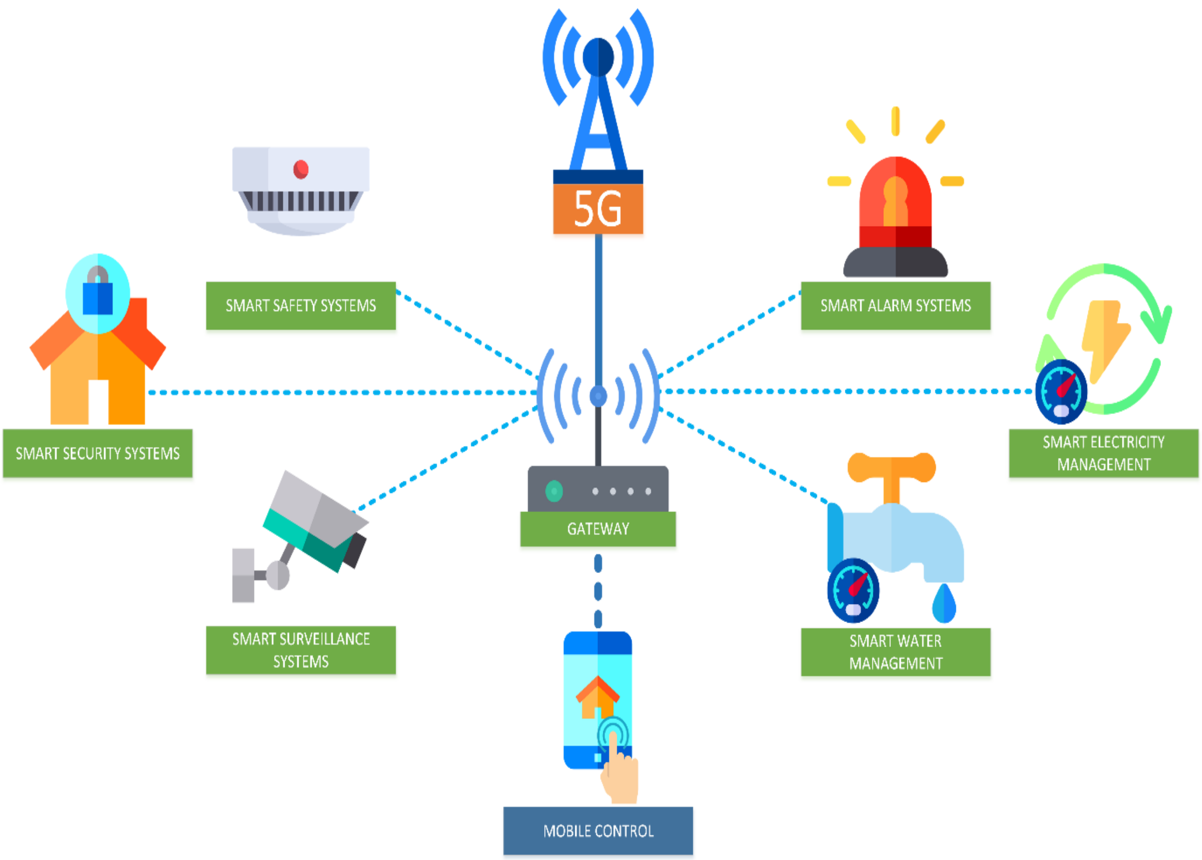

Figure 9.1: Smart Home

Some of impacts are:

- Video monitoring of home, Security & Alarm, Door control, HVAC control, Smart lighting for efficiency, Controlling appliances through Smart phones, Solar lighting system, smart (electricity, water and gas) metering etc.
- Data generated at home will be transferred to mobile devices for Remote monitoring and control of devices/systems. Homeowners could monitor their homes remotely and take required actions themselves.

- Telcos, Security Firms, Retailers, Energy Providers, Cable MSOs etc would compete for this market segment by acquiring smaller niche players.
- Interactive security providers will dominate the smart home services market and partner with those offering energy management and healthcare services.
- Remote Monitoring Service Providers could provide information to Insurance companies so that the later could reduce liabilities from property loss/damage due to smoke, fire, water, etc.
- The traditional operator-controlled STB will have evolved into an advanced cloud-based STB capable of recommending content and relaying it to multiple connected devices around the home. These devices will be deployed widely across Pay TV markets.
- Content based on a viewer's or family's preferences, past viewing history or even mood, would be delivered.
- "Over the Top" content would also be streamed on multiple screens.
- Traditional remote controls will have disappeared, replaced with tablets or smartphones and intuitive controls such as voice and motion control.
- Location based ads where the service provider sends ads according to the current location of the customer.
- "Mood sensors" to detect tiny changes reflect the person's mood and could be used to determine everything from their experience of music, online ads, TV programs, temperature, lighting in the room etc.
- 5G enables AR and VR which gives immersive experience to home viewing. Home users can enjoy events as if they are part of the event. So, they can travel around the world in the comfort of their living rooms. Most important impact will be that they will be able to interact with relatives/friends as if they are sitting in front of them.
- This is extremely delightful as this removes the barriers of distance and times and enables real-time interaction with the loved ones, wherever they are. This can be further extended to business interactions, job interviews, sales discussions etc. This would open up a entirely new world of opportunities.
- People would be able to play on-line games with real players from anywhere in the home.
- Home consumers would now be able to get huge amount of content across multiple devices.
- All smart home appliances and devices can be connected and control available to the home user from anywhere, making living smart, safe and secure.

Smart home offers the ability of remote control through a smart phone or smart device and thereby enhance comfortable and smart living.

Figure 9.2 below, shows the Smart living enabled by 5G.

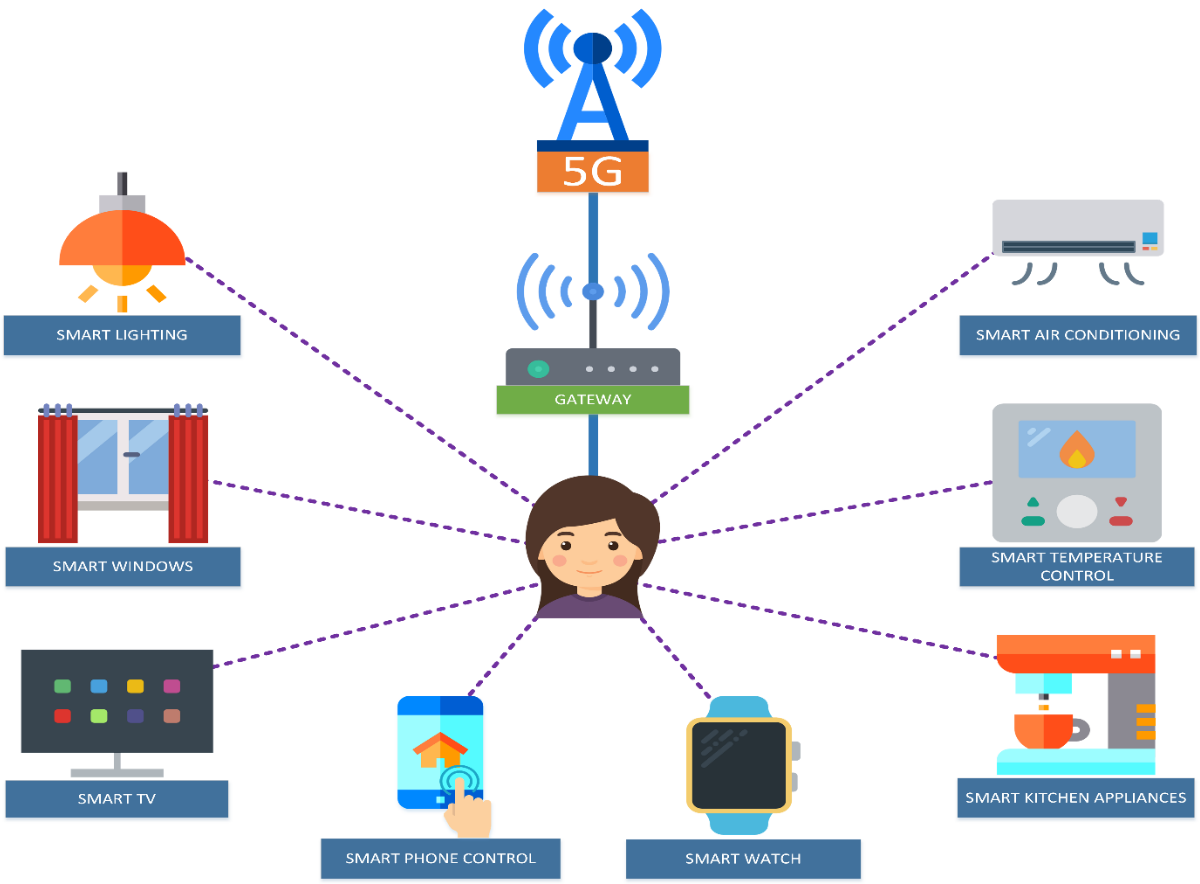

FIGURE 9.2: SMART LIVING

<u>Additional opportunities in Smart Home</u>

Smart home offers the ability of remote control through a smart phone or smart device and thereby enhance comfortable and smart living. The value that the home users get from becoming connected is that they can get insights about them, their homes and their activities across multiple devices and are able to monitor and control their homes. 5g will enable vast increase in number of IoT to support devices at homes, like smart appliances to building management controls.

5G will be able to provide consistency across smart home networking standards and bring disparate devices together making it easy for device installation and maintenance. Low power wide-area network (LPWAN) a feature of 5G, could connect home devices with minimal power and bandwidth requirements directly to internet, bypassing consumer managed home network [3].

Multiple in-house devices can be directly connected to internet without going through elaborate setup resulting in more ease of use. Smart homes can become part of a community/city network, where information about traffic, weather, utilities, and other public services can be shared quickly [4].
Forbes has reported from Globaldata forecasts that there will be a growing competition for smart home dominance. Content owners will be able to deliver content like video-on-demand, direct to consumers. Amazon and google are implementing AI capabilities for device control in home. E-sports and gaming will become dominant at homes and this will open doors to Pay-TV platforms, cinemas, sports stadiums, and casino [5].

Opportunity for the gaming industry includes providing a immersive and visually stimulating gaming experience to players by being able to connect with other players in near-real time. It will also provide opportunities for service providers, advertisers, sponsors, and video game producers to develop and monetize new products and services.

The combination of VR headsets with 5G can provide immersive experience from home to explore places around the world and meet with relatives & friends in different parts of the world, enjoy sporting events, concerts, festivals, meet celebrities etc. Home viewing will increase exponentially, and this will give opportunities for service providers to create new services and products and earn more revenue. There is emergence of Virtual Personal Assistants, like Amazon's Echo and Google's Home, which enables users to control the connected home appliances through these personal assistants.

The forecasted market size of global smart home market in 2020 is USD 40.9 Billion growing to USD 53.45 Billion by 2022 [2]. Understanding of Smart homes and their need is mainly amongst upper end homes in metros. Gartner has predicted that consumer spending on connected home devices will total $ 189 million in 2018 which is 18% increase from 2017. According to their personal tech survey, 7% of users in the UK, US and Germany use some type of smart home access devices such as smart locks etc. Gartner expects that households will use 5G primarily for video and for security and surveillance cameras installed by homeowners. Although not as widespread as video access and surveillance, other usages that could benefit from 5G will be augmented reality and virtual reality [6].

9.1.6 Business Models

Home automation service providers Business Model will have to include partnership with Security companies, Telecom operators, energy management provider, healthcare provider and cable MSOs.
The business model that would emerge is Integrated Home Automation model encompassing all the agencies mentioned above. The business model should harness new revenue opportunities generated

through the connected home devices and the video applications and create new services and products. The model should focus on improving the customer's connectivity, offer multiple services from media entertainment and remote access to home automation and security.

The model should also include insurance company tie-ups, as the Integrated Smart home providers could provide useful information to Insurance companies so that the later could reduce liabilities from property loss/ damage due to smoke, theft, fire, water etc. The model should allow a simplified connectivity to the home user enabling them to install their own 5G home solutions, so that the adoptability will be quicker. The model should enable the flexibility to connect everything from smart appliances to building controls, sensors, and cameras.

The business model should focus on enabling video applications through AR and VR, so that immersive experience could be provided to the user. This would be the killer application and the business model should ensure this. The Content provider partner should deliver innovative applications which could give immersive and a real-life experience. The Business model should focus on new opportunities in gaming through partnership with video games producers, advertisers etc.

Another model is "**Smart Home as a Service Model**". As connected home devices market is increasing rapidly, this can model can emerge. This will have an exponential growth. The solutions offered by model should include Security & Access, Audio-visual & entertainment, Energy Management and climatic control, smart lighting, etc. It can be offered as an integrated service or as a managed service.

9.2 Safety and Surveillance Providers

Safety and surveillance are important for any governments. These are required for ensuring a comfortable and worry-free life for all citizens. Safety and Surveillance covers all use case scenarios ensuring safe and secure environment including but not limited to Video Surveillance, Emergency response, Smart premises etc. The ability to initiate an emergency communication to request help when needed is a right of all citizens, and this ability should be independent of the network and access technologies deployed for voice communications provision or the physical abilities of the citizen. The successful outcome of an emergency call could make the difference between life and death. It is therefore essential for the emergency responders to be provided with accurate location information via an automated process.

Surveillance can be used for various purpose including real time monitoring and alerts to prevent theft or to improve efficiency or to ensure safety. Spread of knowledge and education, coupled with strict vigilance, can help contain security threats. However, for robustness in security, electronic threat detection mechanisms are recommended. The main advantage is the passive monitoring by these electronic solutions, which does not impact routine life of any individual and still ensures safety and security.

9.2.1 Global Trends

Security threat can emerge from many sources like terrorism, snooping, women safety, theft and wrong intensions. All are having far reaching consequences like loss of human life and property, and change in behaviour pattern of individuals, many of them being irreversible. According to a UN report, the worldwide average of the number of policemen is 350 officers per 1,00,00 citizen [7]. Several countries are increasing their efforts to counter terrorism and rising crime. As the nature of crimes are becoming sophisticated, conventional police patrolling does not help. It is required to use technology for battling these crimes.

China has recently introduced piloted a security system is a city, where they have installed an exceptionally large number of AI enabled CCTV systems across the city. They can monitor the entire city and find a person in a crowd, whereas the person moves. They can track criminal movement. This will be the trend in other countries also.

9.2.2 Demand Drivers

9.2.2.1 Consumer Drivers

People demand personal safety and security, as threats are increasing in the modern world. They need to be safe at their homes and in public places. In the event of a threat, they need to authorities to quickly act and save the situation.

9.4.2.2 Business Drivers

Security service providers need a technology that can integrate millions of Cameras across a city, be able to collect pictures of the entire city in real-time and process it. Streets and public places must be continuously monitored, and any threat situation must be analysed. Facial recognition also must be performed to identify certain criminal elements This requires scanning millions of cameras in real-time and performing analysis of the pictures. They would also be using drones for aerial surveillance to get a better picture of the streets. The demand is for excellent connectivity as they must connect a large area which is under their surveillance control. Also, human intervention in the process of surveillance lead to delay and errors and hence sophisticated technology is demanded which can automate the entire process.

9.2.2.3 Government Drivers

Safety and security of the country and its citizens are the prime importance of governments. Tacking an external enemy outside the country borders is straight forward. However, handling the criminals and terrorists inside the country is challenging. This is the prime concern of the Police authorities and Homeland security. Governments have realized that increasing patrolling by policemen is not effective, as the cities must be secured 24x7 and it is very difficult to have a large army of police personnel everywhere. The percentage of officers managing the safety and surveillance of people, is extremely low. This demands the use of technology to manage these services.

9.2.3 Technology Enablers

5G characteristics that will enable the demands for a sophisticated safety and surveillance systems are:

- Bandwidth and data rates: needed to support both uplink and download of video rich services over wireless networks.
- Ultra-low latency: for enhanced user experiences potentially including the delivery of 3D images of the area to be secured.
- Always on connectivity: 5G networks offers the data rates and capacity needed to support video rich services over wireless networks.

9.2.4 Socio Economic Impact

The social impact is that this system will ensure safety and security to people and save lives.
The IoT devices operate 24x7 providing continuous monitoring. The communication channels deployed enables seamless communication between the devices. Automation leads to faster and more reliable response as compared to human Intervention.

Auto Detection of the eventuality by the Devices (Video and audio capturing, Intrusion, Gas leak, High Temperature, Motion Detection, Heartbeat Etc..) will trigger alert with location of Incident to right authorities. Event Triggered by Citizens (Press SOS Button, Call Authorities, SMS, IVR, Break Glass, Etc..) will broad cast the location and details of citizen to the Authorities. The backend systems will Auto identify the Geography of the Citizen and trigger the right agency.

Like in the case of Fire detection, the local fire department will get informed or in case of medical alert, the nearest Hospital/ Doctor can get informed. The Backend system can also identify the nearest responders available and can send alerts to them on the devices they carry (Mobile Phones) with the location of the citizen in distress. No Human intervention to dispatch the responders will bring down the response time of authorities. Since all the Device activities are getting recorded and time stamped, the chances of fake alerts & what happened when is also getting documented.

Some of the Safety and Surveillance use cases, are below:

- City wide Video surveillance systems
- Facial recognition in a crowd, which is extremely useful for tracking terrorists and criminals.
- Video surveillance for Banks, ATM, Jewellery stores and similar establishments
- Home safety (local smart home wireless networks)
- Citizen response management system
- Drone based aerial surveillance systems
- Vehicle tracking systems
- Women / citizen safety in public transport vehicles.

There is indirect economic impact, by preventing crime and terrorism.

Figure 9.3 depicts a city with video surveillance all around.

FIGURE 9.3: SMART SAFETY AND SURVEILLANCE

Additional Opportunity/ value capture

Future security systems will become more so sophisticated with advent of 5G. Security devices equipped with 5G-capable chipsets will consume low power than wired systems and will have superior battery life. 5G offers a path to feature-rich systems that integrate higher resolution cameras with better bandwidth that can send sizeable images through the network [8].

Reolink, a Security Camera manufacturer, is planning to introduce 5G Cellular security CCTV cameras with SIM cards. They would not require Wi-Fi connection & power and support faster download and upload speeds. This would enable very fast upload of camera footage to the cloud or download of recorded videos. It will enable smooth live viewing of 5G outdoor & indoor security camera with almost no lagging time. These cameras, powered by batteries, could support full HD transmission while retaining image quality and resolution [9].

Many countries like US, Singapore etc have video surveillance systems to detect act of terrorism. Chinese government accesses data about its citizens at 5G speeds of up to 10 GBPS provided by Huawei. Multiple personal data streams are used in analysing and predicting individual behaviour. Surveillance such as facial recognition, vehicle recognition, geo-tagging and DNA databases are used to match an individual's location and activities to get actionable insights to any type of threat. Citizens are given social credit scores based on the surveillance, which is used to way they are treated by the government [10].

Typical applications of video surveillance include crime detection and prevention, anti-terrorism, traffic monitoring, forest fire monitoring, unauthorized changes in land, etc. 5G can take video surveillance to a new level in the field of national security by analysing digital images of the terrain and identifying potential invasion, Surveillance UAVs are very effective in its ability to capture images of distant targets in larger areas. Live video captured needs to be continuously transmitted to control centre, which demands robust communication system. These small UAVs have limited communication range, typically line of sight communication with fixed network access points which is could be challenging in mountainous regions. Low latency, higher bandwidth is required. These challenges could be addressed by 5G and MEC.

Autonomous drones flock without any pre-programming or control station. Instead, they communicate amongst themselves and self-organize, split around obstacles, re-join, and avoid colliding with each other. There is no leader among them. They collaborate on the movements. For persistent surveillance tasks, the use of multiple small UAVs organised in flocks can be considered [11].

9.2.5 Business Models

Security providers cannot work in silos as before. They need to work with different providers in a synchronized way to achieve their objectives. This would create a need partnership business models between Security providers, Telecom companies, Cloud providers and Drone operators. Connectivity is especially important. Also, the model should use cloud enabled systems. Model should include partnership with Telecom Operator.

9.3 Content Service Providers

9.3.1 Global Trends

- Young people across the world constitute a new generation eager to consume more content related and instant service. Countries like India is expected to emerge as the youngest nation group in the world by 2020 with 64% of its population in the working age group. The population of the people in the age of 15-34 is predicted to increase 464 million by 2021[12].
- Social media has made most of the people in the world hooked on to their phones and data consumption is heavy.
- Consumer expectations for a compelling viewing experience increases by the increase in the video streams delivered over the top by content providers.
- Video will contribute to bulk of global data traffic by 2020, majority of which will be OTT services such as VoIP, Social networking and messaging
- Internet video streaming and downloads will grow to more than 80% of all consumer internet traffic by 2019 [13].
- OTT streaming will grow as 4K video will become the new standard for consumers.
- Global IP Traffic will grow to 2 Zettabytes (100 trillion gigabytes) by 2019 [13].
- Wireless and mobile devices traffic will rise to 66% in 2019 [13].
- Internet video to TV grew 47% in 2014, will increase fourfold by 2019 [13].
- Consumer VoD traffic will grow to 7 billion DVDs per month by 2019 [13].
- Quality of Content and ease of delivery will be the prime factors.
- Multi-player On-line gaming will increase.
- Consumers are increasingly turning to OTT services and online video both at work and for entertainment. This is the case with industry also, to some extent. This will need enhancement to the mobile networks. These services range from personalised and interactive entertainment services through to support for the virtual office.

9.3.2 Demand Drivers

The consumer demand drivers are:

- Increasing mobile connections and data usage
- Next generation communication and entertainment
- Consumer demand for high quality video

The business demand drivers are increased productivity.

9.3.3 Technology Enabler

5G acts as the technology enabler for this its characteristics that enable these services are:

- Bandwidth and data rates needed to support both uplink and download of video rich services over wireless networks.
- Ultra-low latency for enhance user experiences potentially including the delivery of images and videos
- Always-on connectivity to support services in high mobility environments such as cars, planes and high-speed trains.

5G networks are expected to offer the data rates and capacity needed to support both uplink and download of video rich services over wireless networks.

9.3.4 Socio Economic Impact

- Optimised media delivery services that meet the different usage patterns for content consumption in different contexts such as provision of real-time ultra-high-definition content streaming for watching concerts and sporting events from multiple angles. This includes the having these services in ultra-dense user environments such as popular sporting events.

- Transference and delivery of ultra-high-resolution images such as 4K-UHD (four times the resolution of Full-HD) and 8K-UHD (16 times the resolution), expanding to 3D imaging and hologram services over time.

- Delivery of cloud gaming and video streaming on smartphones and tablets everywhere, including in high mobility environments such as trains, cars and planes.

- Enhancements to working across locations that are enabled by the capacity to share ultra-high-resolution images and video in real-time. While existing 4G technology is currently capable of supporting both multi-person video calling and the high bandwidth data networks needed to draw on data stored in the cloud, rich communications services will support higher resolution images and be available in high mobility environments, facilitating knowledge sharing and collaboration anywhere and at any time.

Additional Opportunity/ value capture

- User/machine generated content from smart devices could help users to share data real time which is likely to improve the user experience.
- Cooperative media production could allow content to be worked upon by different users in multiple locations simultaneously.
- Distributed performance is expected to have the capability of distributed content sourced from different locations in real time
- Immersive experiences: Online AR/ VR gaming of the future will require tactile internet experience (high data rates at low latency). This in combination with voice recognition technology is likely to evolve towards voice interaction with virtual characters through smart wearables.

9.3.5 Business Models

Content Service Provider's business model should focus on strong content creation with IP protection, and direct delivery to end consumers. It should explore new ways to distribute content, by offering high level of personalization for Customers, creating individual channels to explore content that is not otherwise available.

Business model should include bundled offerings delivered through subscription services which will have to be implemented for all types of content including music, gaming etc. Offerings should enable people to seamlessly access content from wherever they are, from different handsets and access points.

Subscription Based Model for Content Service Providers

Content Service Provider aggregates and distributes content from different content producers including VR gaming, music, video streaming etc. User pays a fixed subscription fee for a particular content for a fixed duration.

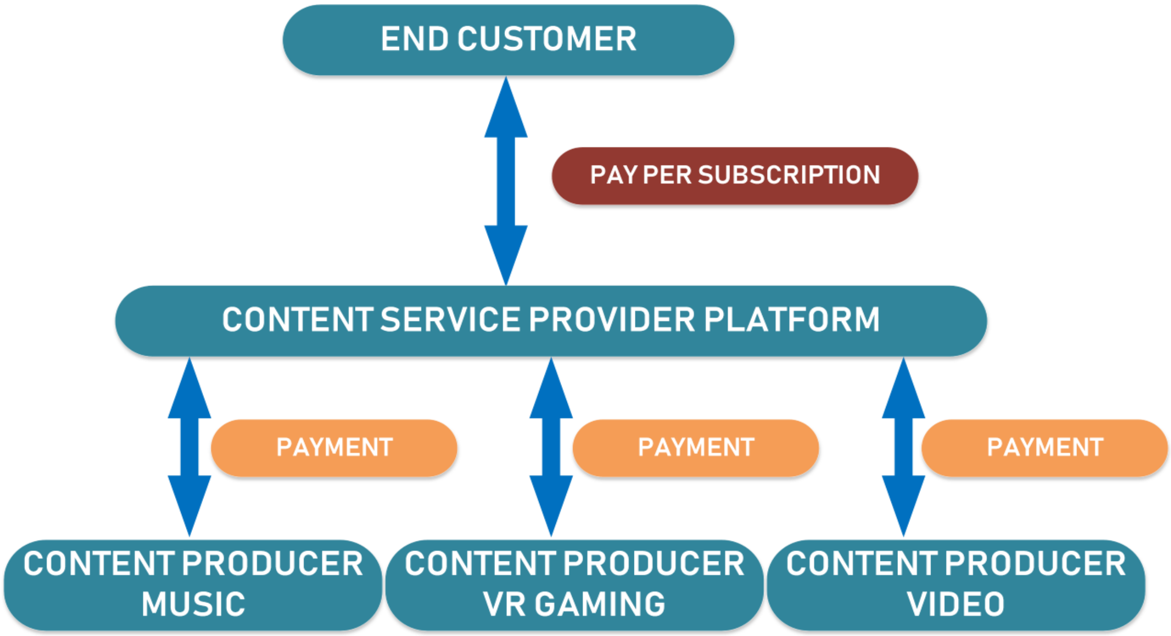

Figure 9.4: Subscription based model for Content Service Providers

Gassman et al. defines such a pattern in their 'business model navigator' as "Subscription" business model pattern, where customer pays a regular fee, typically on a monthly or annually to gain access to a particular content. CSP gets a steady income stream which they can pass it into the content producers [14].

Ahokangas P et al., in their scenario-based business model theory, defines this as "content-oriented business model" under their 4C business model typology, which is built on providing all types of online content-related services like audio, video, text etc which are owned by the CSP or content producers [15].

<u>**Usage Based Model for Content Service Providers**</u>

Content Service Provider aggregates and distributes content from different content producers including VR gaming, music, video streaming etc. User pays a 'pay per view' or 'pay per download 'for a particular content..

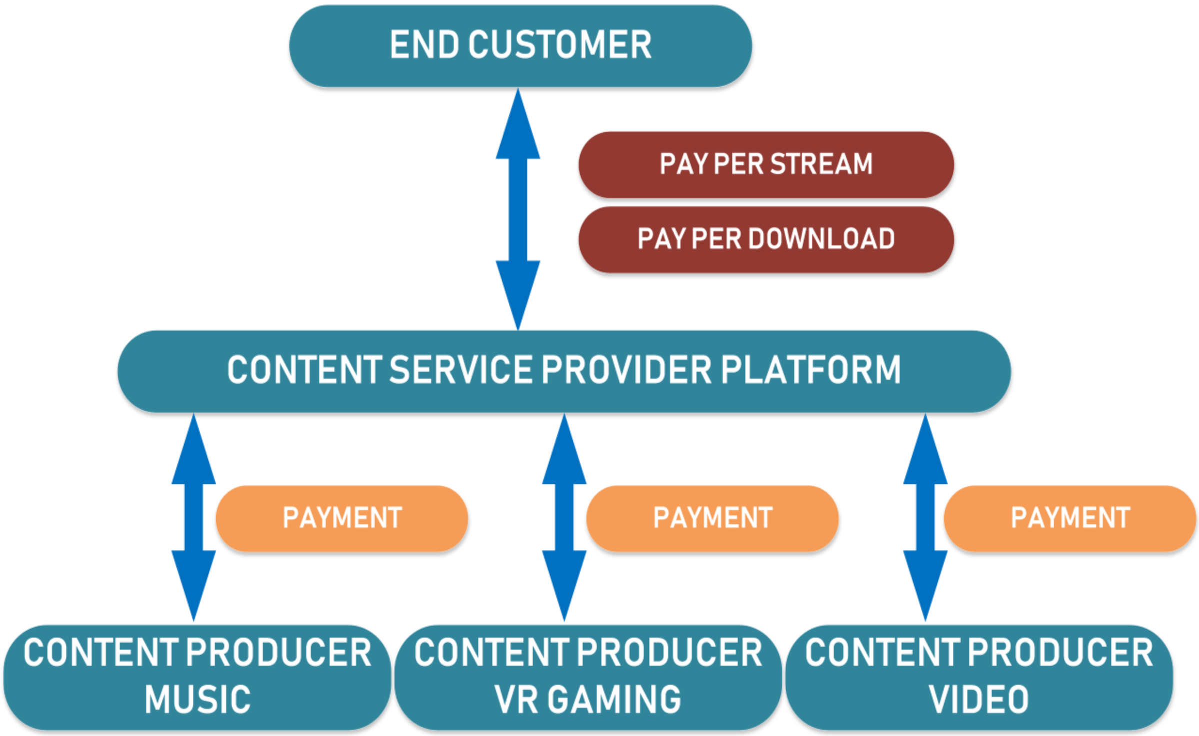

Figure 9.5: Usage based model for Content Service Providers

Gassman et al. defines such a pattern in their 'business model navigator' as "Pay Per Use" business model pattern, where customer pays based on what they actually use or consume. Customer gets the flexibility of consuming only what and when they require, and the provider gets a higher payment for this [14].

Ahokangas P et al., in their scenario-based business model theory, defines this as "content-oriented business model" under their 4C business model typology, which is built on providing all types of online content-related services like audio, video, text etc which are owned by the CSP or content producers [15].

9.4 Enterprises and Businesses

9.4.1 Global Trends

Enterprises:

- The consumption of Digital data is growing exponentially due to the rapid increase in website browsing, social media, music and video streaming etc.
- Increased use of IoT and connected devices will also be a driver for increase in digital data.
- Betanews reports that 2.5 Quintillion bytes (million trillion bytes) of digital data are created every day. 90% of digital data in the world today was created in the last two years. This is created by 3.8 billion internet users which also includes mobile internet users and social media users. They predict that by 2020, the global digital content will be 44 Zetabytes or 44 trillion Gigabytes. The digital content will grow at 40% annually [16].
- Cloud-based services will dominate the enterprise as it has made creation and storage of digital content easier. In 2016, 42% of companies derived more than half of their business through cloud-based apps which in 2017 has increased to 93% using the cloud [16].
- Mobile will be the primary business device and more business will interact on-line.
- Data Centre market will be transformed. Big data will push the need for more storage, network, and computing resources to unprecedented heights.
- Data Centres will consume 1.5 to 2% of global electricity with a consumption growth rate increasing 12% annually [16].
- Software will be critical by 2020**.** Big Data players, App vendors and even a large proportion of network components will be software defined.

Retail Business:

- It is the middle class which drives the consumption and demand for retail business. Increase in growth of middle class along with increase in its disposable income creates demand for new products and offerings and this drives the growth of retail business.
- The size of the global middle class will increase from 1.8 billion in 2009 to 3.2 billion by 2020 and 4.9 billion by 2030. This will come mainly from Asia, where by 2030 will have 66% of the global middle-class population and 59% of middle-class consumption. India and China will be the main contributors for this [17].
- The global middle-class led consumption will rise to $ 64 trillion by 2030, growing at an average rate of about 4% in the long-term. The middle-class consumption in advanced countries has matured and annual growth will be very minimal, whereas it will be as high as 6% in emerging markets like India and China [18].

- Indian economy is growing steadily and has an average growth rate of 7.9%. It's GDP per capita, has grown from US$ 844 in 1985 to US$ 5416.7 in 2014. Such a growth creates a demand for retail goods as standards of living among middle class increases [19].
- Consumers would use smartphones as part of almost every shopping experience, a combination of both online and in-store.
- As per India Brand Equity Foundation, India is one of the largest growing electronics market in the world with a CAGR of 41% between 2017-20 to reach US$ 400 billion. It has the world's third largest TV industry which is expected to grow at a CAGR of 9.8% over 2016-2020 calendar year and is projected to reach US$ 13.31 billion by 2020. Also, it is the world's 3rd largest Smartphone market in 2017 with consumption growing to 14% annually to 124 million units [20].

9.4.2 Demand Drivers

9.4.2.1 Consumer Demands

- In dense urban cities, commuting will be very time consuming and difficult. Employees would want to have the flexibility of working remotely from their homes, at least on some occasions.
- Field force and Sales employees work involves travelling outside the office for majority of their time and they would want to work virtually from anywhere and have all the office systems available to them remotely.
- Employees would want to bring their own devices, which they are comfortable with, for the office work.
- Employees and Consumers would want to use their smartphones for work and purchase activities, respectively.
- Growing purchasing power of the consumer and rising influence of social media creates a demand to spend on good things.
- Would want to compare instantly amongst all retail brands for price, quality and track record of customer service of the retailer, before making a decision to buy.
- Would want to purchase from the convenience of their devices at anytime and anyplace, rather than from the physical retail stores.
- Increasing mobile connections and data usage – OTT services
- Next generation communications and entertainment –Online Video

9.4.2.2 Business Demands

- Increased productivity
- Companies should have their internal systems implemented to allow employees use their own personal devices for work. They should have very good security built-in.
- Need to move business to Cloud as the data usage becomes too high and they would need the elasticity and convenience offered by Cloud services.
- Need to provide instant access of office systems to remote employees.
- Companies need to conduct virtual business meetings to avoid expensive travel.
- Retail businesses need to give consumers virtual shopping experience, so that consumers can virtually visit retail showrooms, look at all products and decide on purchase, at their own convenient time and place.
- Rich communications services refer to next generation of communications designed to meet the needs and expectations of consumers who are increasingly turning to OTT services and online video both at work and for entertainment and Industry looking for increased productivity

9.4.3 Technology Enablers

5G acts as the technology enabler for the above with features like:

- ➢ Augmented Reality and Virtual Reality applications are very important to enable remote working, virtual meetings and virtual retail shopping. These applications need high capacity, low latency and uniform experience features.
- ➢ 5G offers different types of connectivity optimized for different types of services. Apart from enhanced mobile broadband connections, they also support low latency and high reliability services, which are necessary requirements for immersive AR and VR experiences.
- ➢ Bandwidth and data rates needed to support both uplink and download of video rich services over wireless networks. This supports the requirements for Enterprises and Retail businesses for remote operations and virtual representations.
- ➢ Ultra-low latency for enhance user experiences potentially including the delivery of images and videos, required for consumers to view before deciding to buy online.
- ➢ Always-on connectivity to support services in high mobility environments such as cars, planes and high-speed trains to enable all place availability of services.

9.4.4 Socio Economic Impact

Enterprises:

- Companies will have to have complete virtual representations of themselves.
- Move physical office spaces and collaboration into a digital environment. The virtual office building will of course change how businesses are organized and give distributed workforces an entirely new set of tools for virtual collaboration
- Virtual teamwork across organizations and locations
- Companies can conduct business meetings with participants brought together virtually with life like communication through AR enabled by 5G.
- Company planners can collaborate on shared designs with AR and VR, reducing the need for physical modelling and testing, which in turn can reduce time-to-market.
- Employee training can include real simulations of work, which can improve productivity.
- Customers meetings can be held in virtual setting to discuss business without travel delays and associated costs.
- Traditional ADM vendors will have to foray into Mobile development space.
- Enterprises will have to build capabilities for Software defined "Everything" to survive.
- Enterprise Data Centres will need to be able to provide elasticity i.e. be able to keep pace with the ballooning size of their infrastructure.
- Marketing solutions built around virtual reality to enhance products visibility and showcase their application in real world.

Retail Business:

- Retail industry has already had a big impact with e-Commerce and online retail. There will be further disruption from the connectivity enabled by IoT and 5G. It will transform their internal business processes to their marketing methods.
- The logistics systems will have to be re-engineered as the massive connectivity will help them to handle inventory better and manage their supply chain more effectively.
- More connected services could lead to Smart shelves and Smart inventory, which can automatically trigger replacement and replenishments of products going to expire or stock below threshold value. This can lead to full automation with robots handling the warehouses.
- Traditional Retail industry will be threatened and have to re-invent to survive. In-shop experience has to be innovated, as a differentiator, using technology. Shops with cameras using real-time video analytics can sense a customer's mood, so that the staff can assist the customer better providing a more personalized shopping experience.

- Virtual shopping malls with Augmented reality would make On-line shopping the preferred mode of purchase.

Additional Opportunity/ value capture

Retailers can adopt various use cases, through 5G enabled technologies:

- Retail trends, demand and consumption patterns can be determined through advanced instore analytics, providing retailer deeper insights into best pricing and inventory management mechanisms.
- It is a global trend that people first look at the window of the retail shop and would enter the shop only if they find something interesting. It is important for the retailer to identify this prospect and get the prospect inside the shop. This could be achieved by interactive storefront windows with Interactive and exciting messaging on touchscreens linked to motion-sensors which could attract the prospect and invite them into the stores, increasing store footfall.
- Cameras fitted in the racks capture customers' facial expression and analyse whether they are looking at the products in that rack, and if so for how long. It can also track if the customer picks a particular product and the result of that selection. If the product is not selected, did the customer look at the price tag and put the product back etc. This analysis in real time can give valuable insights to customer behaviour and selection process, so that the retailer can address this immediately. Accordingly, this data can be used to send customised alerts on a near real time basis on alternative products, to enhance customer experience and boost sales.
- Beacons: Beacon technology could help retailer to send push notifications to consumer's smart phones/ wearables while in the store. This feature could also help in improving in-store navigation for customers.
- Heat mapping technology: Analysing security footage in real-time using AI-driven algorithms can help retailers understand how consumers move through the store and what could be done to better engage with them.
- Augmented reality enhanced shopping applications can let a customer virtually try the product before deciding on its purchase. This ensures reduction in rejections when the product is delivered. Furniture businesses can use this application to ensure that online buyers and virtually fit the furniture in their homes and see if it fits inside the space and how does it look in the room. Customers can view the product in 3D inside their homes to ensure that the products fits in well.

To compete effectively, retailers need to consider reacting to the needs of the tech-savvy digital consumers. With 5G, retail companies could use innovative technologies with more data speed and reliability, gather more data, and ultimately create more business opportunities, augment revenues and building long-lasting relationship with satisfied customers.

9.4.5 Business Models

The Enterprise business models should ensure that the following are taken into consideration.

- Companies will have to have complete virtual representations of themselves.
- Move physical office spaces and collaboration into a digital environment. The virtual office building will of course change how businesses are organized and give distributed workforces an entirely new set of tools for virtual collaboration
- Virtual teamwork across organizations and locations
- Traditional ADM vendors will have to foray into Mobile development space.
- Enterprises will have to build capabilities for Software defined “Everything” to survive.
- Enterprise DCs will need to be able to provide elasticity i.e be able to keep pace with the ballooning size of their infrastructure.
- Marketing solutions built around virtual reality to enhance products visibility and showcase their application in real world.

The retail business model needs development of systems so that Fashion consumers would be able to experience products before they purchase them, such as trying on clothes in the virtual world. The implications of this for clothing retailers and consumers would be nothing less than revolutionary.

Business Model should ensure that offerings include

- Creation of Virtual shopping malls
- Provision of On-line shopping with Augmented reality features and
- Provision of additional interactivity on the Smartphone to give enrich the retail experience

9.5 IoT/ M2M System Integrators

9.5.1 Global Trends

- ABI Research predicts that more than 30 billion devices will wirelessly connect to the Internet of Everything in 2020 [21].
- According to ABI Research, Industrial IoT (IIoT) Connections will surge to 66 million global connections in 2017.The largest growth of IIoT connections is happening at Asia Pacific region. The global connection is forecasted to grow by 18 million new IIoT connections annually by 2021. 25% of these connections will be wireless in 2017. This will significantly grow over the next few years [22].
- Prices of sensors, bandwidth and processing costs have dropped significantly in the last 10 years. Sensors prices have dropped to an average of 60 cents. Bandwidth cost has decreased by a factor of 40 times. Processing costs have declined almost 6o times [23].
- Gartner predicts that worldwide IoT Security Spending will reach $ 1.5 billion in 2018 and that regulatory compliance will become the prime influencer for IoT security uptake by 2021 [24].
- According to Deloitte and Nasscom report, the number of connected devices globally are expected to grow from 3.8 billion in 2014 to 20.8 billion by 2020 with a CAGR of 33% and revenue is expected to grow from $0.9 trillion in 2014 to $3 trillion by 2020 with a CAGR of 21% [25].
- Deloitte and Nasscom predicts that globally IoT market growth will be driven mainly by connected devices in Manufacturing and Automotive industries with approximately 0.7 billion each by 2020. Automotive industry is expected to have maximum IoT growth to reach $303 billion by 2020. Transportation and Logistics together, is expected to have IoT revenue of $491 billion by 2020 [25].
- The fastest growing market for IoT is India, with expected 1.9 billion units and market value of $9 billion by 2020. IoT adoption is expected to grow across Utilities, Manufacturing, Automotive, Transportation, Logistics, Healthcare and Retail. Investment of $1 billion is planned for the IoT requirement in the 100 Smart Cities [25].
- According to Cisco, the Internet of Everything will create USD 14.4 trillion in total value during 2013-2022, enhance job growth and make companies more secure [26].
- According to Gartner forecasts, 8.4 billion connected things will be in use worldwide in 2017 and will reach 20.4 billion by 2020. Total spending on services and devices will reach approximately $2 trillion in 2017 [27].

9.5.2 Consumer Drivers

IoT can be considered as the aggregation of many M2M connections and goes beyond communications to sensors, actuators, high performance data analytics and other IT systems, which together can perform many intelligent tasks in different domains. IoT will allow an increasing number of things to be connected. ITU defines the IoT as a global infrastructure for the information society, enabling advanced services by interconnecting physical and virtual things. IDC estimates that the number of interconnected devices will reach approximately 30 billion.

The consumer drivers are:

a) Increasing mobile connections and data usage

- Increasing number of mobile devices
- Increasing use of data-based services like mobile applications, OTT services etc.

b) Next generation communications and entertainment

- Games and Videos are increasingly becoming popular.

c) Reliability expectations - demand for always on mobile services

9.5.3 Business Drivers

The business drivers are:

a) Mobility as an enabler of increased business productivity - ability of employees to work from any location on any device

b) New Services/ Enhanced existing services – increased adoption of cloud

9.5.4 Technology Enablers

5G features that enables IOT adoption on a large scale are:

- **Device Connectivity** -5G can enable a large increase in the number of connected devices to wireless network. This could also exceed the number of traditional mobile connections like phones.
- **Energy efficiency:** The massive increase in connected devices making up a fully formed IoT is likely to require better energy efficiencies than currently possible, with some mobile broadband devices required to be on all the time while others will turn on intermittently. These energy efficiency needs could be supported by two 5G characteristics like support for up to 10 years of battery life for low power machine type devices and 90% reduction in network energy usage.

- **Always on**: Some potential IoT services will require ultra-reliability and availability, such as healthcare and automotive functions, where an outage in service availability could have life-threatening effects.

The highly scalable and contextual proposed nature of 5G networks could support the diversity of IoT applications with differing requirements for pricing, mobility, latency, network reliability and resilience

9.5.5 Socio Economic Impact

- Growth in sensors to monitor physical or environmental conditions, that cooperatively pass their data through the network to a main location. These networks will increasingly be used in many consumer applications like - industrial process monitoring and control, machine health monitoring etc.
- Module vendors and independent Application Development Platform providers would have been acquired by large SIs and major Carriers who will exert greater control over the end-to-end solution by acquiring IP that will allow them to control applications, software and endpoints
- New OTT value chains and sensor networks will have emerged in IoT and we can expect emergence of cross-ecosystem partnerships.
- IoT will be built on M2M foundations but will become integrated into clothes, cars, public spaces and most goods in FMCG markets.

Following is a list of possible IoT Use cases:

- Remote Surveillance & Security
- IP based video surveillance
- Automatic alarm to prompt incidents
- Fleet Management
- Vehicle tracking
- Logistics
- Supply Chain Management
- Inventory tracking etc
- Building Automation:
- Energy control
- Entry control & security
- Consumer & Home
- Smart Meters
- Integrated Home entertainment networks

- Monitoring
- Healthcare
- Utility / energy industries

9.5.6 Business Models

IoT/M2M System Integrators business model should be that of partnership with other ecosystem providers like Telecom Operators, Smart City implementers, Industrial automation implementers, Healthcare providers, Intelligent Transport System providers, Security consultant, Home automation consultants etc.

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10.0 Socio-Economic Impact of 5G on Smart Cities

10.1 Introduction

The legacy agricultural economy is fast moving towards industrial and service economy resulting in large scale migration from rural areas to urban cities in search of employment, better education, and healthcare. Cities are getting densely populated creating problems in their management. This has created a need to relook at the very concept of the city and the city administrators must find ways to make the city liveable and sustainable and thereby 'smart'. The living standards of the city residents must be improved with sustainable infrastructure, reliable utilities like power/water/waste management, good healthcare, education, safety, and security. To achieve the smartness, the city must be well interconnected and communication system is vital to the success of the smart city. A city is a complex environment consisting of various applications, activities and services across different domains and infrastructures and this needs to be integrated to work together effectively for that city to become Smart.

The level of services to make a city 'smart' cannot be standardized across all countries, as it depends on the stage of development the country is in, its available resources and the necessities of its people.
Also, the smartness will continuously evolve with technological innovations. An innovative city using different technologies to offer services which improves citizens' standard of living is considered as 'smart' as it ensures economic, social, and environmental sustainability [1]. However, the basic function of the smart city is to ensure adequate living needs like water, electricity, sanitation, transport, good governance, safety and security, education, and quality healthcare, to all its people [2]. Also, these services should be made available remotely to communities which are underserved [3]. All the services should be integrated so that their delivery and the management can be controlled by the central administrative agency.

This chapter analyses the global trends in Smart Cities and the various demand drivers from the citizens, governance and businesses necessitating the 'smartness' in the city, leading to the role of ICT technologies in their implementation. Further, the limitations of the current ICT systems are analysed, and the role played by 5G technologies in implementing them, is discussed. Few Smart City applications and services enabled by 5G, are listed. The business model ecosystem, for successful Smart City implementation, is further discussed.

10.2 Global Trends

World population is currently 7+ billion and is growing at a rapid pace. There will rapid urbanization with people moving to cities in search of jobs, healthcare, education etc. This will be the phenomenon in developing and under-developed countries, especially in Asia and Africa. However, in some of the developed countries in Europe and in Japan population has remained stagnant or is declining. This is also creating a problem of ageing population and the governments here have to the cities livable for the ageing population.

UN states that 30% of world's population lived in cities in 1950, which increased to 54% in 2014 and is expected to grow to 66% by the year 2050. 82% of North American people live in urban areas, whereas it is 80% in Latin America and 73% in Europe. Africa and Asia have been mainly rural but growing fast towards urbanization now. India has the largest rural population of 857 million and China has 635 million. However, these two countries are rapidly growing with large scale migration happening towards urban areas, mainly in search of jobs. The population growth and urbanization are projected to add 2.5 billion people to the world's urban population in 2050, with majority concentration in Asia and Africa. India is projected to add 404 million urban dwellers, China 292 million and Nigeria 212 million [4]**.** So, the governments in these countries will have to take adequate measures to make the cities sustainable.

There are about 1000 smart city pilot projects worldwide, out of which about 500 are in China alone. China has about 500 smart city pilot projects which is the highest in the world, according to Deloitte. China aims to nurture 100 new smart cities from 2016 to 2020 having started this initiative in 2012 and is using AI and IoT in traffic management, law enforcement and energy management [5]. Shanghai is progressing well to become a truly smart city. A 'internet plus' strategy is implemented which is expanding connectivity across every domain of city life like education, healthcare, environment etc. It is focusing on tech-led healthcare and education [6].

India launched its ambitious "100 Smart Cities Mission" in June 2015. A budget of USD 15 billion was allotted for this. The 100 cities were to be selected based on a Smart city challenge, where cities will have to compete for funds. Each city must create a corporate organization, headed by a dedicated CEO to implement smart city. Each of the selected city would get USD 150 million which will have to be equally shared between the Centre and the State. Any additional requirement would have to be raised by this company from financial markets. 100 cities were selected over 5 rounds of selection [7].

In USA, 66% of cities are investing in Smart City technology and 25% of those without any smart city systems are exploring how to implement it, according to a report from the National League of Cities. The main applications areas of their implementation include Smart meters for utilities, Intelligent traffic signals, E-governance, Wi-Fi kiosks and RFID sensors on pavements [8].

In EU, 78% population lives in cities and 85% of the EU GDP is generated in cities. Cities are the driving forces of the European economic and societal growth [9]. There are about 240 European cities with population of greater than 100,000 using technology for their transport management, energy management or any other infrastructure management i.e they use some smart city applications. Europe smart cities which stand above others are Amsterdam, Barcelona, Copenhagen, Dublin, Helsinki, and Manchester [10].

According to Australian Government Report on Smart Cities [11], Australia launched its Smart Cities Plan in Apr 2016, to build an agile, innovative, and prosperous nation. It is an AUD 50 million Smart Cities and Suburbs program to support delivery of innovative smart city projects.

Cisco forecasts that Global IP video traffic will be 82% of all consumer internet traffic by 2021 [12]. This is primarily due to the increased video services used by youth or 'Digital Natives', whose population is increasing. The demand for the connected cars is increasing globally, as per a report by 5G Americas [13]. The cars shipped with connectivity features were only about 7% in 2013. The global car sales in 2020 is expected to be around 92 million, out of which 69 million will have connectivity features i.e. about 75% of cars shipped globally will have connectivity features.

Recently ITU has established a new ITU-T Study Group 20 (SG 20) to address the standardization requirement of Internet of Things (IoT) technologies, with an initial focus on IoT and its applications in smart cities.

10.3 Demand Drivers

The demands for a Smart City include the services and applications required for enhancing the quality of life for Citizens by ensuring their social and economic well-being by improving the City's infrastructure, and those required for better City Governance. These services and applications are expected to be delivered through mobile telecom networks, exponentially increasing the mobile traffic in cities. The main drivers for this increase in mobile traffic are the demands from Citizens, Governance bodies and businesses, for the use of these services on mobile network.

10.3.1 Citizen's Demand Drivers

Citizens demand good city infrastructure along with services and applications for a better social and economic wellbeing. They demand reliable and affordable utilities like water, power, transportation and communication, safety and security, access to quality education and healthcare, transparent governance, and ease of interacting with government agencies. Further to this, they would want to have enhanced quality of life at home and in the city.

There is increasing crime in cities along with social unrests and terrorism. For safety, Citizens demand efficient real time monitoring through 24x7 video surveillance of all public places and quick response to prevent crimes. There should be quick access to Healthcare, even for Residents who are not close to hospitals by providing systems for remote health monitoring. This is especially important for elderly and infant care. Citizens also want safe, secure, and smart home leading to smart living. Access to quality and affordable healthcare and education is required irrespective of their location.

Citizens should be able to control and manage different systems of their home, even remotely and integrating those with home security systems. They should be able to access education services remotely, to enable literacy and better job opportunities. Next generation communications and entertainment – Online Video for Smart homes and Security/ surveillance requirements leads to demand of high-speed communication services. This is further increased by greater adoption of social media and demand for on-line entertainment by the present-day youth or ‘digital natives.

10.3.2 Governance Demand Drivers

The main demand drivers for Government are:

- To provide services and applications for a better city infrastructure
- To implement systems for economic development
- Improve quality of life for citizens.
- Optimize the cost to serve citizens
- Make city environmentally sustainable.
- Ensure revenue increase by different utilities by preventing leakages of resources.
- Implement systems to increase productivity of citizens leading to increase in tax revenues.

City Governance must develop infrastructure to deliver reliable and efficient supply of basic amenities like water, power, gas, waste management. Good roads with efficient public transport systems and traffic management are basic requirements. The requirement for reliable water supply is the ability to monitor its quality at various supply points and its pressure and flow in real-time, so that water leakages could be accurately detected and plugged. This reduces losses and increase revenue collections. The requirement for an efficient Waste Management system is its ability to monitor and regulate the waste handling by real-time tracking and directing the waste collection vehicles. The requirement for efficient public transportation is to integrate various modes of transport enabling common ticketing and central control of all services.

Requirement for Traffic Management is to have a central 24x7 traffic monitoring and control system which is also integrated with other services like fire engines, ambulances, and police systems to enable easy passage during emergency situations. Also, smart street lighting is required for energy savings.

Requirements for ensuring safety and security of citizens include 24x7 video surveillance of streets and all public places like shopping centres, bus stations, railway stations, airports etc and ability to analyse them in real-time and take protective actions. This will also require integration with data from other sources for quick identification of individuals and ability to identify certain individuals in a crowd.

Citizens should be encouraged to generate power through renewable sources like roof-top Solar to take care of their internal needs and enable them to connect extra power generated back to the grid and earn revenue for the same. Smart metering should be implemented to communicate with and control the customer premise equipment, for real-time monitoring of the usage, so that the entire City supply can be efficiently balanced and controlled.

Currently in many countries like India, the above services happen in isolation. Different departments of governments work independently. There are no linkages between these services and hence data collected in a department's 'service' is not available to other 'services'. This is based on author's personal experience in India. The Smart City mission objective of the Government is to integrate data of these departments to enable creation of Smart City. The concept of 'smartness' is by integrating these services to enable intelligence/ information gathered in any 'service' is available to all other 'services. An important requirement for a smart city is that it must remove silos existing between various city departments and those existing between government and private enterprises [14].
The author would like to substantiate this with opinion of global Industry leaders [15].

1) Raymond Johansen, Governing Mayor of Oslo, has stated that the objective of smarter Oslo is to get out of the internal silos and work across sectors.
2) Kajsa Ollongren, Dy Mayor of Amsterdam, has stated that Smart city meant collaborating amongst various municipality departments, companies, start-ups, knowledge institutions and citizens.
3) Edwin Diender, VP for Government and Public utility sector for Huawei, has stated that the limited uptake in the deployment of smart city initiatives can be attributed to information systems that sit in silos and implementation of smart cities calls for the integration which is able to bring together information in silos [16].

4) City Protocol, a global organisation facilitating Internet of Cities, has stated that the first job of a smart city is to cross city silos by creating an informational and operational web that can enable disparate systems to collaborate with each other [17]
5) US Department's Smart City challenge giving $50 million prize, was for cities to remove silos and connect systems together [18].

Disaster management and emergency response being a vital role of the Government, requires effective integration of various applications like hospital systems, ambulance systems, fire engines and emergency towing systems.

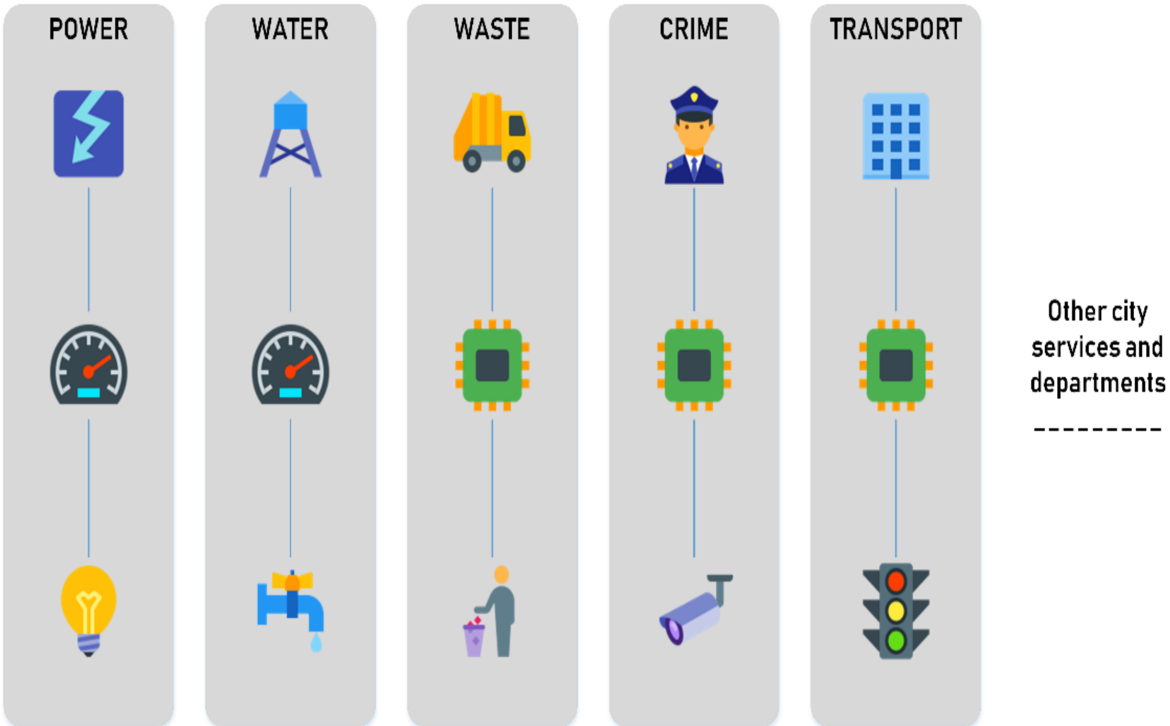

Figure 10.1: Independent City Services and Applications.

Figure 10.1 shows various city's utilities, like power/water/ waste management/ transport/ crime/etc., having their own independent services and applications. These services and applications do not interact with each other.

Finally, the systems should enable transparency and ease of use in all its service like payment of taxes, property registrations, payment of utility bills etc. and should be convenient for citizens.

10.3.3 Business Demand Drivers

Smart Cities will create new services and/or enhance existing services which create new business opportunities leading to additional investments which would create new jobs. The drivers for the Businesses would be to expand into new markets leading to new revenue opportunities and increase the productivity of the employees leading to higher profitability. Productivity will have to be enhanced with increased mobility enabling employees to work from any location at any time.

The new businesses created would result in the following demands

- New services will be delivered through mobile applications leading to digitally connected cities. This would result in exponential increase in mobile connections and data usage. The demand will be for Over-The-Top services and mobile applications.
- Mission critical services will have to delivered in real-time and this demands ultra-high reliability of the communication system which must remain always-on.
- The demand will be for cloud adoption, as companies will have to have flexibility in expanding their business.
- The demand will be for development of video entertainment and security/ surveillance services and robust mobile communication systems for their delivery. The mobile communication system should support extremely high speeds and low latency to handle virtual and augmented reality services.

10.4 Smart City Implementation Requirements

Successful implementation of Smart Cities requires robust Information and Communication Technologies (ICT) to automate the city functions and enable effective services delivery, whereby human intervention is minimized giving rise to transparency in the system

Connectivity is the basic enabler for Smart Cities. The ICT requirements can be classified as:

1. Ultra-reliable communications with features of High reliability, high availability, and low latency down to 1ms end to end.
2. Enhanced mobile broadband: where High speeds ae measured in Gbps,
3. Massive IoT: These needs to be low cost, low power and should be communicable inside buildings also. IoT has emerged as one of the primary requirements for Smart Cities.

The services and applications of Smart Cities are delivered through a large number of Internet of Things (IoT) applications, wherein billions of sensors and actuators monitor and control various functions of the City. Critical identified locations in the city will have to be interconnected with devices like CCTV cameras, sensors, RFID tags, Mobile devices, embedded SIMS, actuators etc.

The requirement is for Machine-to-Machine (M2M) communications. These low power devices must be connected by fixed or mobile networks. Fixed networks are challenging to implement as they are expensive and, in many cases, not feasible. Mobile networks are ideal in these situations. Devices with embedded SIMs could easily communicate on a wireless network to aggregators. The backhaul can be wireless or optical fibre based fixed networks. ICT performs remote control and management of all elements needed in the Smart City ecosystem.

Real-time availability of data across different vertical applications to City administrators and control systems, is crucial to Smart Cities. ICT enables integration of all services and applications and provides central control to the City administrators. Huge amount of city data must be collected, aggregated, and communicated with back-end controllers for analysis in real-time to enable appropriate response. The City administrators should have real-time knowledge of the city functioning. Also, other systems and agencies should be able to access this data instantaneously, as required for effective functioning of their part.

Advanced predictive analytics aided by high performance computing systems and Artificial Intelligence algorithms, are required for instant decision making. This needs setup of advanced Data Centres and Cloud infrastructure, which integrates different city applications to enable them to leverage and make use of value provided by each other. Officials from different Verticals can make their decisions based on common data and this collaboration in vital.

Some of the Smart City services that ICT must implement and integrate are Public Utilities like water, power, waste management, Healthcare, Transport systems, Homes, Security, traffic management, education, streetlight management, building management etc. These services and applications must be integrated, and the control made available to Integrated Command Centre, which should provide a single picture of all integrated city level services. The system could have multiple smaller intermediate command centres feeding information to the main centre. The ICT system should be highly secure, reliable, and scalable.

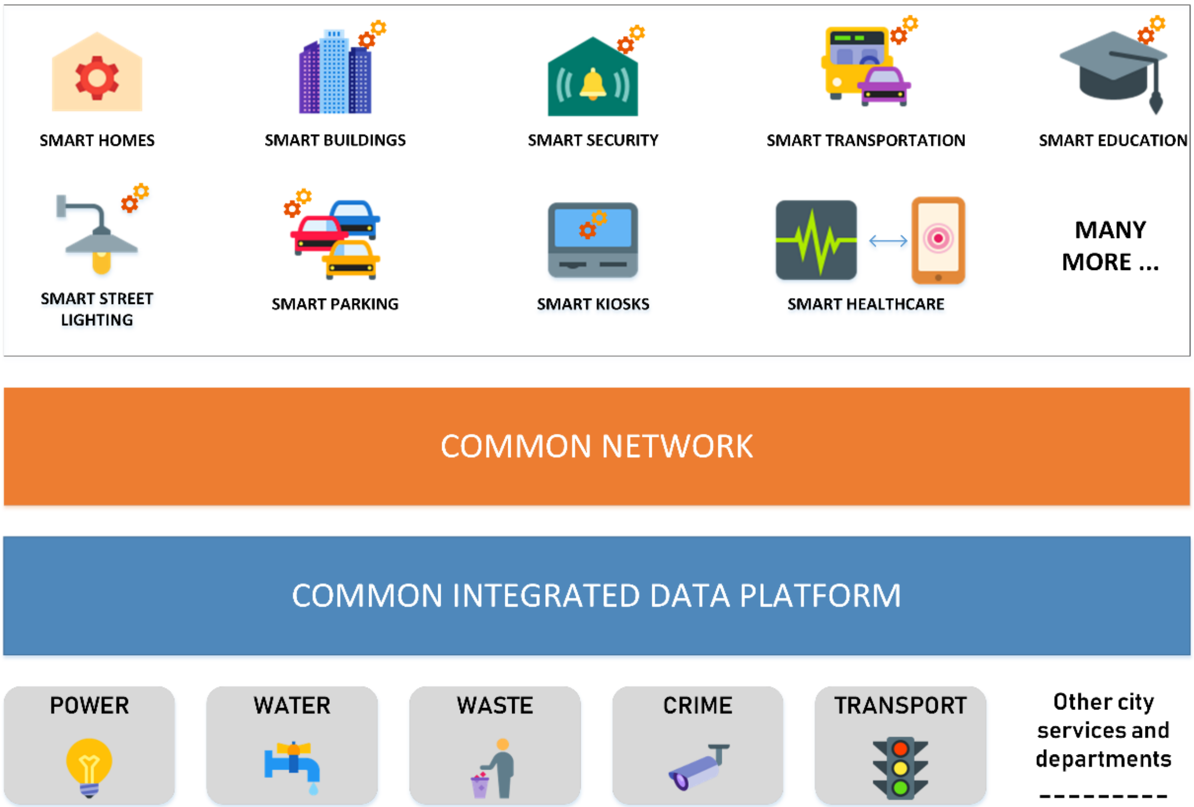

Figure 10.2: Integrated Smart Services and Applications

The Figure 10.2 above, illustrates integration of various services and departments of a city, enabling data sharing amongst each other as required to provide a holistic view and control of the entire city's functioning, making the city smart.

Thus, ICT is used to automate city functions, enabling effective services delivery, wherein human intervention is minimized giving rise to transparency in the system. This would ensure that the players involved in Smart City including Citizens, Businesses, Government officials etc would work cohesively together, leading to effective management of the city.

10.5 Current Limitations in implementing Smart Cities

Connectivity is key to the common infrastructure on which various applications are deployed, to allow data sharing amongst them. Network requirements are also changing. 24x7x365 connectivity is required between PCs, Human to Human (H2H), Human to Thing, Thing to Thing and Machine to Machine and this connectivity must be ensured indoors (even inside buildings), outdoors or on the move. This calls for a need for an effective Communication Network with reliability of greater than 99.9999%, little end-to-end delay of around 1mS, support of extreme density of IoT devices, very high bandwidth and support of longer device battery life.

The current 3G/4G systems has limitations in meeting the above requirement. There is capacity and reliability limitations for wireless backhaul/ fronthaul. These connections are mostly wired and will be expensive or may not be feasible for unplanned deployments. The reliability of the wireless connection may not suit mission critical applications. The latency or the end-to-end delay is long and not suitable for real-time applications. The energy consumption of devices is too large to meet battery life duration targets. The high density of IoT devices is not supported as the communication overhead of low rate IoT communication breaks optimized functioning of 3G/4G networks.

10.6 5G – Smart City Technology Enabler

The advanced features of 5G as described in Chapter 2, can meet the requirements of Smart City like the massive adoption of IoT supporting a huge increase in the number of devices like sensors, cameras, actuators etc connected to wireless networks which are required in homes, streets, traffic junctions, public places like bus stands, railway stations, airports etc. This will enable Smart Traffic Systems, Smart Homes, Public safety and Security and Surveillance requirements of Smart Cities. The massive increase in connected devices making up a fully formed IoT is likely to require better energy efficiencies than currently possible, with some mobile broadband devices required to be ON all the time while others will turn ON intermittently. This energy efficiency feature is supported by 5G.

5G supports the large bandwidth and high data volumes required for uplink and downlink of video rich services. User experience enhanced by 3D images and holograms, process industries, multi-player gaming, connected cars, autonomous vehicles, real-time traffic management, security and video surveillance etc need ultra-low latency communication systems which is supported by 5G. 5G also supports diverse use cases requiring relaxed latency like remote meter reading for billing purposes.

5G supports 'always on' connectivity which is required in many healthcare services to prevent life threatening situations. 5G also supports diverse use cases requiring low volume of information like cargo tracking in shipping industry etc. The highly scalable features of 5G supports the diversity of IoT and other applications required for Smart Cities, with differing requirements of latency, network reliability and resilience.

10.7 Social Impact of 5G on Smart Cities

Figure 10.3 below, show of the smart city applications and services, which are enabled or delivered more efficiently by 5G.

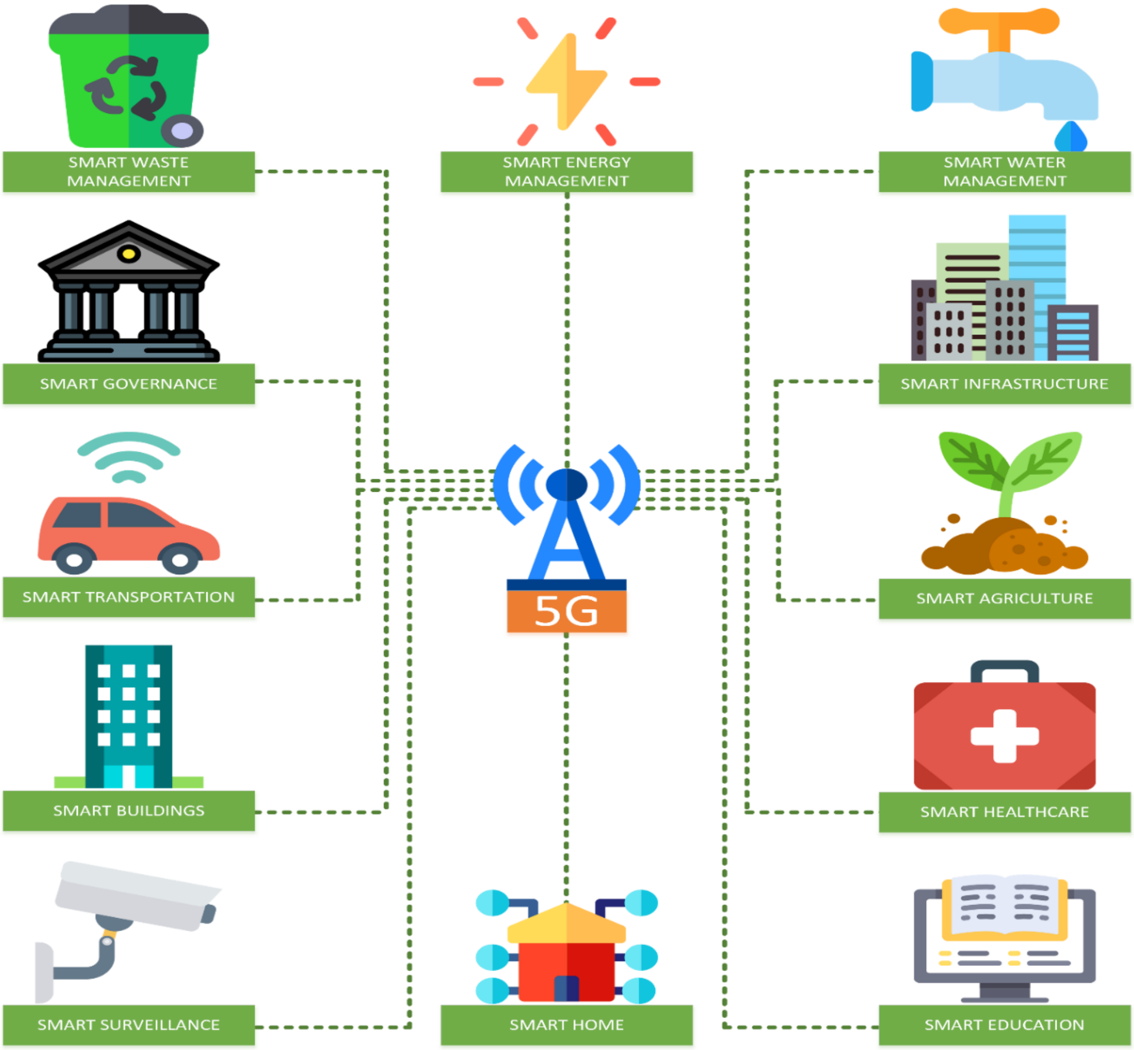

FIGURE 10.3: SMART CITY APPLICATIONS

10.7.1 Smart Homes

A Smart Home satisfies the needs of its residents while they are inside as well as outside the house. The needs include remote monitoring and control of the homes for security, surveillance, enhanced comfort, energy efficiency, entertainment, remote control of home appliances, management of children and elderly etc. Homes will be full of connected devices, not only providing information on their environment but also communicating with each other and become massive sources of information generating large amount of data. It will have a Home gateway platform that accepts different technologies as its inputs, combines them and communicates with the centralized monitoring system. Advanced sensing and control features are provided. They offer the ability of remote control through a smart phone or smart device and thereby enhance comfortable, secure, and smart living.

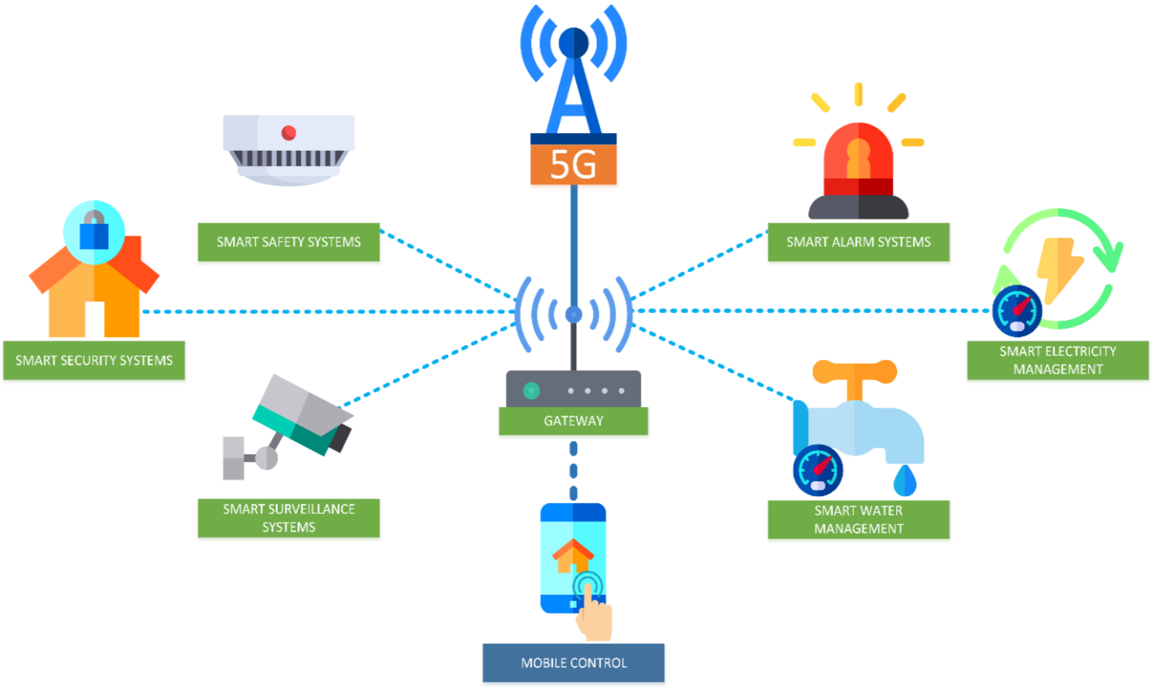

FIGURE 10.4: Smart Home - Mobile Control

Figure 10.4 above illustrates Smart Home enabled by 5G. Mobile phone will become the control device for most of the home applications with Smart TVs, Smart Gateways, Games Consoles and even tablets becoming the main hub for delivery of entertainment content in the home**.** Ultra HD TVs will become mainstream with hundreds of Pay UHD channels being available in addition to plentiful streaming UHD services. Homes will have a multitude of 'TV screens' and seamless transferring of content between those screens will become a mainstream activity. 5G will enable instant download and play of a full-length film. Mobile TV will dominate as it provides enhanced personal viewing experience anytime-anywhere access. Data generated at home can be transferred to mobile devices for remote monitoring and control of devices/systems. Homeowners could monitor their homes remotely and take required actions themselves. OTT content can also be streamed on multiple screens.

10.7.2 Smart Education

5G will enable remote access to multimedia learning disrupting the traditional way of education by enabling learning anytime at anyplace, removing the need for classroom-based system only. Connectivity and network-based solutions will become essential infrastructure. The constraint of physical classrooms will be removed, and learning will become virtual with technology enabling virtual and augmented reality features. Massive Open On-line Courses (MOOC), enabled by connectivity, will become the norm. Students will be able to choose their course of choice from global players. A **connected world** means that most parents will be able to transparently follow, and be involved in, the learning process of their children.

Education experience will be enhanced by virtual and augmented Reality. This will improve understanding-based learning among students. These services can be customized for education by introducing possibility of interaction with the learning object, making the learning process more fun and interesting. VR can create virtual presence of the students in a classroom, even if they are far. Immersive AR can enable new ways of learning and team working in education through services such as mobile cloud classroom and Virtual Presence. Teachers can get necessary information about each student and be aware of their needs and capabilities for a more personalised teaching. Students/ learners can participate in virtual field trips without leaving their place.

Education systems will have eLearning modules for all offered courses, so that course delivery can be made with blended classroom and remote classes. eLearning would be available on smartphones/ tablets and would provide interactive learning. This would be enabled with cameras on remote student computers or smartphones/ Tablets. Students would be able to interact with teachers in real time. The high speeds and ultra-low latency features of 5G enables the above features and pave the way for smart education. Teaching will need to adapt to both the physical and virtual classroom. The teacher's role will change to be a coach and guide.

10.7.3 Smart Health

5G will enable access to healthcare anywhere and at any time, paving the way for effective healthcare through remote delivery. Features like real-time medical data management, VR based medical training etc will emerge. Remote patient monitoring will be a key impact as 5G will support the continuous monitoring and processing of numerous sensory devices, thereby increasing the effectiveness of preventive care. Remote patient monitoring enables patients and their family members to track vital information like blood pressure, weight change, glucose levels and other vital signs while eliminating majority of the unnecessary data that is not warranting a clinical intervention and a hospital visit. Hence, Remote Patient Monitoring will become increasingly prevalent in the healthcare industry.

Connected healthcare supported by 5G will make better healthcare available to more people, regardless of location and 5G will make centralized patient records more accessible, leading to more efficiency and better outcomes. It will enable transition to home-based care system which has benefits of cost saving to the patient and less burden on Government on hospital needs.

Other health applications enabled by 5G include:

- Telemedicine through audio and video conferencing
- Teleradiology and imaging will help in remote diagnosis by facilitating real time exchange of imaging data like CT scan, X-ray etc for expert advice.

- Robotics assisted remote surgery
- Integrated health record maintenance systems with patient's EMRs stored in network or cloud storage, can be instantly accessed in case of emergencies
- Interactive 3D Brain imaging
- Implanted medical devices communicate vital parameters of the body functions.
- Local paramedics/ surgeons can be trained or advised in real-time by remote specialists leading to tele-surgery.
- Smart medication which prompts or administers prescribed medication through embedded connected devices. This greatly helps highly diabetic and asthma patients.

5G's enablement of superior healthcare has the potential to substantially facilitate a transition from volume-based fee for-service models of medical delivery to outcome-based models.

10.7.4 Smart Transportation Systems

Smart transportation systems include low-emission mobility, multi modal transport and integrated mobility solutions**.** Some of the services related to smart city include:

- Traffic management
- Parking management
- Tolling management
- Electric vehicles charging infrastructure
- Integrated mobility management

Most of the road accidents occur at traffic intersections and at the merging lanes of highways. 5G can enable Vehicle to Vehicle (V2V) communications and Vehicle to Infrastructure (V2I) communications, wherein vehicles can communicate with each other and with central control systems about their location, speed, direction of travel, braking and other vital parameters. This can send warning messages to other vehicles traversing in the same direction, about their intention to enter/depart a highway so that collisions can be avoided at merging lanes. Vehicles entering a traffic junction, where visibility of all oncoming vehicles from sideroads could be hampered due to tall buildings or trees, could be able to get a 'bird's view' of the vehicles coming through all the roads. This would reduce collisions at junctions. Automatic braking when the car detects an obstacle will also likely reduce a significant number of rear-end collisions. Also, hazardous road conditions can be detected, and safety systems can guide drivers on alternative routes to allow them to drive more safely and lower the risks of accidents. Cars with sensor based built-in driver assistance systems, 3D imaging and augmented reality dashboards, can overlay information on top of what a driver is seeing through the front window, identifying objects even in the dark and can inform drivers about the distances and movements of the object [19].

Cities are highly crowded with vehicles moving bumper-to-bumper at a slow pace. This is stressful to drivers and consumes lot of time resulting in health problems and loss of productivity. Also, finding a parking place is difficult in cities and this adds to the loss of time and increases stress. 5G would enable driverless vehicles or autonomous vehicles, which would have a positive impact on the health and productivity of citizens and is expected to prevent accidents caused by human factors. The high capacity and mobility features of 5G enables in-vehicle infotainment needs of drivers and passengers.

10.7.5 Smart Safety and Surveillance Systems

Provision of safety and security to the residents is an important role of smart city governance. There could be security threat from theft, riots, and terrorism. This can lead to loss of human lives and can have adverse effect on the social life of residents. The social impact of 5G is that it will enable systems to ensure safety and security to people and save lives.

City wide video surveillance systems at identified locations like railway stations, bus stations, airports, malls, streets, religious places etc. will help to identify safety problems and respond immediately to security situations. City wide traffic surveillance cameras should allow viewing and recording of traffic conditions, and traffic accidents with greater clarity. Video surveillance at ATMs, Banks, Jewellery stores and isolated roads etc are important for safety of citizen's safety.

5G in Smart City will enable integration of real-time video observation with access to specific locations. This would enable facial recognition to detect known criminals or detecting a person in a crowd. This, aided by simulation modelling and analytics, can help in crime prediction leading to crime prevention. The IoT devices operate 24x7 providing continuous monitoring. The communication channels deployed enables seamless communication between the devices. Automation leads to faster and more reliable response as compared to human Intervention.

Auto Detection of any eventuality by the large number of sensor devices, will trigger alert with location of incident to Authorities. Event Triggered by Citizens, like press of SOS buttons, Call Authorities, SMS, IVR, Break Glass, Etc, will broadcast the location and details of the citizen to the Authorities. The backend systems can automatically identify the location of the Citizen and inform the appropriate agency. For e.g., in case of fire detection, the local fire department will get informed or in case of medical alert, the nearest Hospital/ Doctor can get informed. The Backend system can also identify the nearest responders available and can send alerts to them on their phones with the location of the citizen in distress. Response time is reduced as human intervention is avoided to dispatch the responders. Also, recording

with time stamping can keep track of these events and avoids fake alerts. In event of an accident, the communication system in the vehicle initiates emergency call to the accident control central system for immediate despatch of response team to the accident location.
5G enables drone based aerial surveillance systems to track places which cannot be covered by CCTV cameras.

10.7.6 Smart Power

5G enabled Smart Grids can make detailed coverage of the energy eco-systems and will support accurate, real-time analysis of power consumed and power outages. With 5G, large number of unconnected energy devices can be monitored and controlled in real-time to allow accurate forecasting of power demands, by their integration into the grid. This could help in load balancing and probable reduction in energy cost to the houses. This brings in efficiency and enables value added low-cost services. Networks become self-healing resulting in faster fault identification and restoration.

Consumers will have better choice of the quality of power supply, thereby eliminating the need for investing in expensive accessories like voltage stabilizers, uninterruptable power supplies etc. Advanced Metering Infrastructure (AMI) would allow them to view their power consumption accurately on a regular basis and manage loads based on Time of Use (ToU) i.e use appliances when tariffs are low. They could save money on their electricity bills by shifting loads from peak hours to non-peak hours. They would be able to remotely turn ON/OFF their appliances. The legacy centrally controlled power sector would change to becoming user-centric giving the choice to the consumer to become 'prosumers'. They can produce their own energy using roof-top solar PV for their personal consumption and put excess generated back into the grid, thereby earning revenue for that through net metering.

5G can enable Smart Street Lighting, as the multitude of devices and sensors in the street can track pedestrians or vehicles in real-time and lower public lighting during times when there are no pedestrians or vehicles in the street.

Utility companies would be able to collect data from the Customer Premise equipment at pre-defined intervals while being able to get instantaneous alarms. It will support automated billing data reads, automated load profile reads, automated meter event log data collection, on-demand power quality data reads, on-demand billing reads and would also support remote meter disconnection, as required.
Utilities will have to invest more on renewables to reduce CO_2 emissions. They must now integrate and co-exist with private power producers and prosumers.

10.8 Economic Impact of 5G on Smart Cities

The smart city solutions having the most impact are Energy, Transportation, Security, Education, and healthcare. Smart City Solutions applied to management of power grids and vehicle traffic would result in savings and benefits of hundreds of billions of dollars ($160 Billion) through reduction in energy usage, fuel consumption and energy usage. 5G solutions would enable cities to reduce commute times, improve public safety and generate significant smart grid efficiencies [20].

5G networks would be built using small cell networks and would involve 10 to 100 times more antenna locations than 3G/4G networks. Apart from delivering the high speed and capacities of 5G, these cells would support the increased number of devices that would be connected to the network of the future. Telecom Operators are expected to invest $275 billion in 5G infrastructure, which could create new 3 million jobs and boost GDP by $500 Billion [21]. The new 5G network infrastructure would itself create lots of jobs.

Governments should support the installation of the new 5G infrastructure, as there is going to be a shift from the traditional tall telecom towers to small cell sites installed on lamp posts to utility poles. This may require change in the way the present permission process and fee structures.

According to a study conducted by the New Policy Institute, every transition from the current generation of mobile communication to a new generation, creates lots of new job opportunities in its installation and deployment and from other services which are enabled from that generation [22]. This would have a positive impact on the GDP.

The global market for Smart Cities is projected to reach USD 1.2 trillion by 2020. US has the largest market worldwide. APAC is the fastest growing market with a CAGR of 21.2% [23].

The global smart cities market was valued at USD 529.55 billion in 2017 and is forecasted to reach USD 1.944 trillion by the end of 2023, with a CAGR of 24.21 % during 2018-2023 [24].

According to Frost & Sullivan, the business opportunities created by Smart Cities is going to be over $2 trillion by the year 2025 [25].

10.9 Smart City Business Models

Cities are complex systems having multiple stakeholders and are constantly evolving, changing, and undergoing reconfigurations. Hence, one business model cannot suit all cases. Technologies implemented need to be flexible and cities need to keep their 'digital options' open. Also, it depends on the economy of the cities i.e on the resources available with them for implementing. The business model must accommodate different life expectancies for various infrastructure services. Utilities like water, electricity, gas, roads, and housing must be implemented for a long life, whereas infrastructure like electronics sensors, control devices etc must be designed for shorter lifecycle to accommodate technology advancement.

The evolving business models for smart cities should take from the conventional 'Connectivity' business models to 'Service integration' and "Special Application' business models. First, the city must be interconnected completely. Based on this connectivity, new business opportunities must be created. Then, various services must be integrated within the infrastructure. Then it should lead to new value-added industries to create new jobs. Business model should focus on building a fully integrated converged digital infrastructure. All smart cities initiatives must be done with citizens' consultation.

Smart city business models must clearly define the cost model to the implementing agencies and the revenue sharing model amongst various stakeholders. The services and the convenience offered to citizens, should be at a reasonable and affordable cost to the citizens and should also ensure that the various investors get reasonable return in the long term along with some revenues to the Government. The funding sources can be from the Federal Government grants, City government funds, Public Private Partnerships, World bank grants and debt financing. The sources of revenues are the charges levied on the users for various services including Property Tax, Water charges, Power usage charges, Professional Tax, Entertainment tax, Advertisement Tax, GST, toll charges, parking fees etc.

Smart City Governance and the various Smart City service providers like communication providers, technology providers, software companies, system integrators etc, will have to define their own unique business models. Business models followed by all the above entities should ultimately benefit the citizens. Also, the business models should ensure data privacy of citizens and should ensure safety and security.

Smart city cannot be represented by one business model. There would be multiple business models which have to work together in a co-ordinated way.

Lindgren P, has defined a concept of 'Smart City Business Model Eco System (SCBMES), where he shows that the Smart City concept when combined with Business Model Eco System (BMES) approach would result in better sustainable smart cities. Any SCBMES can be defined by related to the seven business model dimensions and can have more BMs offered by different businesses which are not aligned to any core business model. However, any of these BMs can be defined as consisting of the seven generic BM dimensions [26].

"Smart Cities" Business Model

Value Proposition – This defines what the smart city project should deliver and the problems that should be solved. Smart City business models should be 'outcome based' with a total focus on outcomes of the implementation. It should set targets and measure the outcomes.

For example:

- Crime reduction by X%
- Renewable energy increase by Y%
- Parking revenues increase by Z%
- CO_2 emission reduction by A%
- Number of new jobs created to be greater than XXXX
- Water leakage reduction by B%
- Road accidents reduction by C%
- Reduction in city commute time by D%
- Disaster/ Emergency management response time reduction by E%

Customers or Users – Customers can be defined as those who pay for the smart city services. These could include vehicle drivers passing through a toll and paying a toll charge, or those who do not pay money but pay with other value. In general, the users are as follows:

- Citizens
- Government agencies:
    - Municipal corporation
    - Public utilities departments
    - Law enforcement agencies

Value chain functions – These are functions required to create, capture, deliver, receive and consume value proposition to its customer. The activities required to define and implement various smart city applications are as follows:

- Real-time city-wide monitoring
- Smart city command centre operation
- Emergency response systems and teams for:
    - Crimes
    - Fires

    - Floods
- Crime prediction systems and threat response teams
- Parking spot navigation assistance
- Adaptive traffic signal control
- Smart grid management
- Mobile-based interaction between citizens and city services
- AI/ ML based data analytics
- Socio-economic enhancement based on the urban data gathered

Competences –

- Technology awareness and implementation skills for surveillance systems
- Citizens' ability to adapt to the technological changes such as:
    - Adaptive/Dynamic traffic signals
    - Smart metering for public utilities
    - Mobile-based interaction with city services
- Technology awareness and implementation skills for smart public utilities
- Advanced data analytics capabilities to capture synergies between various functions occurring in a city
- Well-trained and well-formed threat response teams and emergency personnel

Network –

- Municipal corporation
- Law enforcement agencies
- Public utilities companies
- Telecom operators
- Smart city implementers
- Smart city command centres
- Surveillance system providers
- Sensor network providers
- Utility sensor suppliers
- IoT gateway and M2M device manufacturers
- IT infrastructure companies
- Data analytics developers

Value formula – Determine cost structure for implementing directly or through outsourced system integrator or through partnerships. The source of funding must be determined. They often require multiple investors and different sources of capital.

Governments will have the overall responsibility for implementing. The main value for the governments would be in terms of enhancing quality of life for the residents, as described in earlier sections. They will have to decide on the way of getting revenues to handle the implementation and delivery of services. For each smart city application, it is required to determine who would be paying for the service and take responsibility of risks. Will it be public, end users, third parties or Government itself? The recipients of the revenues must be determined for each service along with any revenue sharing requirements. How does residents pay for the service they receive – would it be free, subscription fees, usage fees, 'pay-as-you-go' fees etc. These would service specific. For e.g. for service like city wide video surveillance for crime prevention, it would be expenditure directly from the government without taking any specific fee from residents. However, government would have covered these costs through indirect taxation. For services like a new road, flyovers, elevated corridors etc which are made for the convenience of residents, government could charge a usage-based toll fee.

Revenue models should include:

- Usage based fees – Consumer of services pay directly for eg. Road tolls, entrance fees of parks etc. The mode of payment can be
    - 'fixed subscription' fees, where the consumer pays fixed amount for service irrespective of the level of usage.
    - 'pay-as-you-go', where the consumer pays for each use of the service.
    - Consumption of utilities like water, power etc.

Other ways of revenue could come in by selling value generated to other third parties. For eg, selling advertising space, monetization of anonymized data generated.

Other ways of revenue could be

- Value capture – It can be 'Direct' value generated directly within a project, using strategies such as revenue sharing, profit sharing, refinancing gain share, user fees, and impact fees. Indirect value capture creates value because of investments, for e.g., developing a new transit system, that benefit developers. A government might also capture more value from a project, for example, swapping a piece of public land that a developer wants for a piece of privately-owned property.
- Asset sale- Government could sell or lease a public asset to a private entity for value and then uses the proceeds to fund future investment.

Relations – This will determine how the smart city project maintains its relationship with all stakeholders, such as:

- Residents
- Service providers
- System integrators

- Various governments departments and officials

The project utilizes an integrated IT platform which brings all these stakeholders together. It can help maintain relations like:

- Joint Venture – Government can have a joint venture with a private company to jointly deliver a service, where the best of both the parties are utilized.
- Public -Private- Partnership (PPP) – Government contracts with a private company on long term for provision of an infrastructure service which may involve construction and payment would be made on this service availability.
- Franchising – allow government assets to be operated on a commercial basis to generate returns.
- Privatization – The complete service implementation, delivery and operation is given to private sector, independent of government's control subject to certain regulations.

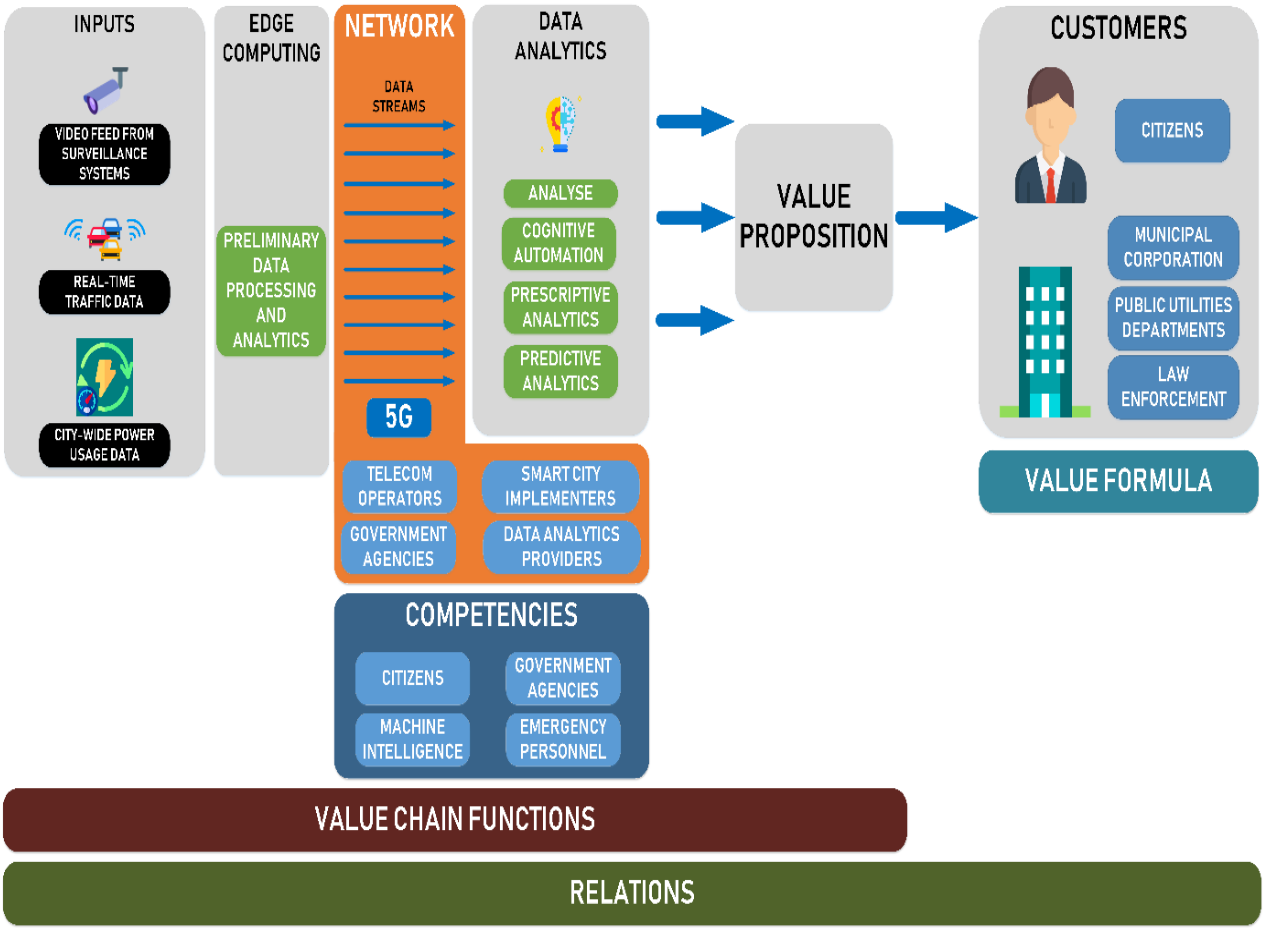

Figure 10.5: "Smart Cities" Business Model

10.9.1 'Area-based development' Business Models

At the outset, Business Model should focus on the area to be developed and should design based on either improving that area or re-development of that area. They could also choose a greenfield area and create a new model for that.

10.9.1.1 'Retrofitting' Business Model

This is basically city improvement. Government can decide on target places based on size of the cities. The objective is to make the selected target area more efficient and liveable. Existing structures will be retained intact in this model. Only many smart applications will be packed into the mostly existing infrastructure and hence will take a shorter time to implement. This model will be the most preferred one as it is not possible to change any buildings or existing infrastructure in a busy city. Only areas of improvements will be analysed and implemented with least disturbance to the city people. Small infrastructure improvements like building flyovers/underpasses to ease traffic, implementing metro trains for transport etc can be done.

10.9.1.2 'Redevelopment' Business Model

Redevelopment will affect a replacement of the existing built-up environment and enable co-creation of a new layout with enhanced infrastructure using mixed land use and increased density. Redevelopment envisages an area which is more than that of the retrofitting model. For instance, a new layout plan of the identified area can be prepared with mixed land-use, higher Floor Space Index (FSI) and high ground coverage.

10.9.1.3 'Greenfield development' business model

Greenfield development will introduce most of the Smart Solutions in a previously vacant large area. Greenfield developments are required around cities to address the needs of the expanding population. Pan-city development envisages application of selected Smart Solutions to the existing city-wide infrastructure. Application of Smart Solutions will involve the use of technology, information, and data to make infrastructure and services better. For example, applying Smart Solutions in the transport sector (intelligent traffic management system) and reducing average commute time or cost of citizens will have positive effects on productivity and quality of life of citizens. Another example can be wastewater recycling and smart metering which can make a huge contribution to better water management in the city.

10.9.2 ‘Smart City Implementation’ Business Models

Various smart city technology and infrastructure providers can build certain portion of the smart city requirements and offer it to the City Governance for a price. Telecom Service Providers could build 5G based digital networks which includes city-wide sensor network and offer this as a service i.e. ‘**Digital Network -as-a Service” model**. Existing large apartment and mall builders could monetize their already existing assets like CCTVs, networking equipment etc by offering **“Video Surveillance as a Service”.** IoT Technology companies can build and offer “**IoT Network-as-a-Service**”. Large land developers could build digital infrastructure in their layouts and offer them as a service to Smart City.

The possible business models for the City Governance, which is ultimately responsible for the Smart Cities, are as below.

10.9.2.1 ‘In-house’ Business Model:

In this Model, the City Governance itself could build the complete city infrastructure, develop, and implement the smart applications and manage the delivery of the smart services to the citizens directly. They must design the complete smart city solution on their own including the various applications and services required. They must identify the right technology solution provider for each application and manage the sourcing. This includes the hardware and software required for the implementation of smart cities. Hardware could include equipment like CCTV cameras, Smart electricity meters, Smart water meters, sensors, actuators, switches, controllers etc. Software could include Artificial Intelligence, Big Data, Machine Learning, etc. They must partner with the right communication service provider for planning and implementing the communicating links and bandwidths. They must build the solution and implement them. They must manage the delivery and the on-going maintenance.

Here, the complete investments and on-going expenses are borne by the Smart City Governance. The revenue is by the fees it collects from citizens for the services used like water, power, gas, parking fees, toll charges etc and from other services rendered.

However, they may not have the expertise and funds to implement smart cities on their own. This is not their area of expertise. This is not a right approach as the services will not be competitive and may prove expensive for citizens.

10.9.2.2 "Partner with System Integrator" Business Model

In this Model, the City Governance would plan and design the smart city solution on their own and/or with the assistance of expert consultants in this area. They could then engage a System Integrator to build the infrastructure, develop and implement the smart applications and services. Then, they could take over the complete control of the infrastructure and smart services and handle the on-going service delivery and operations directly.

Here, the System Integrator will have to be a large company having expertise in building infrastructure including networking, developing, and implementing software applications etc. They could do all these functions on their own or form an alliance with multi vendors including companies that specializes in Mobility, IoT, mHealthcare, Security, Transport, Utilities etc. The SI becomes responsible for sourcing and implementing all the required hardware like CCTV cameras, Smart electricity meters, Smart water meters, sensors, actuators, switches, controllers, routers, gateways etc. They also need to plan and implement the right communication links. They need to develop software applications including AI, ML, Big Data, etc. They must program manage the entire solution build and implement and perform successful trials. They need to finally handover the completely tested and working smart city applications / services to the city governance along with complete documentation. The City Governance takes over the working smart city applications and delivers directly to the citizens. They manage the on-going operations.

Here again, the complete investments and on-going expenses are borne by the Smart City Governance. The revenue is by the fees it collects from citizens for the services used like water, power, gas, parking fees, toll charges etc and from other services rendered.

10.9.2.3 "Public Private Partnership (PPP)" Business Model

The City Governance could call for a competitive bidding for agencies to completely handle certain portion of the smart city infrastructure, implement smart services, deliver, and operate the services on an ongoing basis. They could impose strict regulations on the bidders with regards to the minimum service levels and maximum fees to be collected from citizens. They will have no other role to play. They may have to form partnerships with various service providers who will invest and provide technology for certain services and share the revenue generated from the public for utilizing these services.

The private company performs the functions which are traditionally performed by the City Governance for an extended period. They invest and build the complete infrastructure including software applications and shoulder all the operational risks. They handle and manage the communications required for smooth working of the smart city, by partnerships with Telecom Service Providers. Further, they must manage the proper functioning of the smart city operations on a 24x7 basis and are responsible for the compliance of the service level agreements. The revenue model for the Private party includes User fees or payment from the City Governance or a combination of these.

This model is the most advantageous for City Governance as it does not involve investments and associated risks. However, it could have its own challenges as the objectives of various partners would be different. Challenges are high cost of infrastructure and applications, uncertainty on the return on investment (RoI) and high technology obsolescence. The investments in the smart cities must pay by itself I.e. it should be able to generate revenues from citizens to get a decent RoI and ensure that the costs and quality of services are reasonable for the citizens. The City Governance objective must be to ensure good services are made available to citizens at the least cost, whereas the objectives of the private partners are to get maximum and quick return on their investment. Smart cities should not be financial burden for all the players involved – the City Governance or the private partners or the citizens.

10.10 Opportunity created by Smart Cities

Opportunity/ value capture of each smart city vertical is explained in detail in the respective chapters.

Services and Applications for better City infrastructure:

- Intelligent transport and traffic management – Managing traffic could be easier through controlled traffic signals and sensors regulating the flow of traffic throughout the city in response to demand. This would enable smooth traffic flow without any traffic congestions. The traffic light signalling system would be integrated with other services like ambulances and police to enable easy passage to them during emergencies.
- Smart grids and metering systems with smart streetlight – Enabling better management and conservation of energy, thereby, keeping a check over pollution and further reducing outages.
- Power utilities can detect energy theft/pilferage on near real-time basis and would be able to prevent it. They can perform remote meter configurations, meter fault detection, dynamic tariffs, power quality monitoring, load control, automated meter event data collection, on-demand billing reads and will have the ability to disconnect service remotely, if bills not paid. They can manage load curve by introducing Time of Use (ToU)/Time of Day (ToD) tariff and demand response which will lead to improved grid stability and self-healing grid. They can shift from carbon based to clean energy resulting in green economy.
- Solid waste management – Improving operational costs by optimising routes for garbage trucks through elimination of unnecessary pick-ups, providing dynamic collection routes and schedules for a complete optimisation of the collection operations.

- Smart Street Lighting – Adequate and efficiently managed streetlight can be delivered through automatic turning on/off by sensing users on the street. This would lead to energy savings.
- Smart water supply – Utilities can ensure good quality water supply by being able to monitor quality at various points of supply – from storage, distribution and at end consumer premises. Pressure and flow can be monitored in real-time and water leaks and water thefts can be detected. This would lead to improvement in revenue collections for the utility companies.
- An integrated public transport system with tracking, can be implemented which integrates all modes of public transport like buses, trams, metro trains, ferry etc. Single ticketing can be made for all these modes of travel. Real time tracking of all modes of transport and announcements would ensure that commuters can have just-in-time access to departure and arrival times.

Services and Applications for better social and economic well-being of Residents:

- Video surveillance and analytics – Providing surveillance and security services enabling assurance and mitigating concerns over safety. One of the problems faced in urban cities are increasing crime, social & religious unrest, and fear of terrorist attacks. The city can be monitored 24x7, trouble spots can be identified, and preventive/ corrective measures take very quickly. This may include 24x7 video surveillance of streets, public places like passenger stations (Bus/train/airport etc), shopping centres etc and intelligently analysing them to detect criminal activities. Facial recognition can be used to identify individuals in a crowd, to spot criminals. There is also a need for integrating this data with data from other sources (like driving licence, passport, student IDs etc) for comparison and taking quick action. Homes should be made secure by providing 24x7 security through remote surveillance and control.
- Smart health -- There should be quick access to Healthcare, even for residents who are not close to hospitals by providing systems for remote health monitoring and can transition from present specialist drive hospital-based system to a patient centred home care model with remote delivery of healthcare service. This is important for elderly and infant care. This would result in a huge cost savings for patients. Government's Medicare expenses can also be reduced
- Tele-care and telemedicine would provide new opportunities for providing medical care to the home, including ways of monitoring well-being and improving the medical information available to healthcare providers. Tele-care can be administered through audio and video conference.
- Precision medicine opportunities - New pharmaceuticals embedding connected devices could be used for the treatment of asthma, diabetes and multiple sclerosis, and the management of chronic diseases and pains in general.
- Tele radiology and imaging opens opportunities in remote diagnosis and imaging by facilitating real time exchange of imaging data like CT Scan, X-Ray etc for specialist advice. In emergency care like

accidents, enable instant retrievals of patient EMRs stored in network storage and cloud data storage, which can be lifesaving.

- The energy usage in homes could be smartly managed by controlling of light and other appliances and integrating it with the home security systems, leading to Smart Homes.
- Smart energy includes enablement of consumers to become prosumers, i.e. they can produce energy as well as consume it, have better choice of quality of service, have flexibility of purchasing power from different sources and reduced outages and downtimes.
- Smart homes would deliver remote monitoring of homes and control of devices/systems, getting video content based on family's preference across multiple devices, and immersive experience to home viewing through AR and VR.
- Intelligent transport systems include advanced driver assisted systems with predictive alerts, rear-collision warning system, lane departure warning, blind spot detection, collision avoidance, pedestrian detection, emergency call response, voice-activated alerts via mobile phone, warning of an upcoming traffic incident or public transport service disruptions, real-time web and app-based comparisons of multiple routes or transportation modes and how long they would take, recommended departure times to avoid being stuck in traffic and/or transport delays, GPS navigation visible on car windshield etc.
- Education opportunities would be made available to all, irrespective of distance to the teaching institutions, be enabling high speed remote access of classrooms. This would encourage people to study and increase literacy and enable better job opportunities. Smart education would include enablement of experiential learning by real-world environment simulation, remote access to multimedia learning, interactive learning through smartphone/tablets and virtual classrooms
- Utility companies are required to communicate with and control customer premise equipment, for real-time monitoring of the usage, so that the entire City supply can be efficiently balanced and controlled. This brings the smartness to the service. Residents should be allowed to generate power through renewable sources like roof-top solar, so that the internal needs are taken care of. They should be able to connect extra power generated back to the grid and should also be able to earn revenue for the same. This would vastly address the growing demand of power in developing cities.
- Immersive experience to home viewing. Home users can enjoy events as if they are part of the event. So, they can travel around the world in the comfort of their living rooms. Most important impact will be that they will be able to interact with relatives/friends as if they are sitting in front of them.

Opportunities for businesses:

- Telecom operators could provide integrated service offerings based on their own capabilities enriched by a partner's content and specific applications. They could also partner with 3rd party provider or with OTT provider, wherein the partners could directly make offers to the end customers enriched by the operator network or other value creation capabilities.

- Businesses can become 'Mobile Virtual Network Operator' and work as extensions of Telecom Operators addressing their niche markets. They could provide telecom services by purchasing capacity from telecom operator. They could do end-to-end customer and service management and deliver their own products/ services. Telecom operator could lease their unused capacities to many MVNOs thereby increase their market share very quickly.
- Telecom operators can become 'Digital Service' provider by extending beyond providing core connectivity services and transitioning to providing digital services like TV/ video content, Financial services, Education services, Smart homes etc. They could get direct revenues from both 'own' and 'other operator's' subscribers, which could include Subscription revenue, Advertisement revenue, In app purchases. They could indirect revenues from their own subscribers through increased data users, improved customer retention, increased Data ARPU and customer analytics monetization.
- Micro Operators could share spectrum with established telecom operators and provide their own services independently.
- There will be opportunities for business to create new services and/or enhance existing services. Also, business could expand into new markets or geographies like rural or unserved markets, leading to new revenue opportunities. This will lead into additional investments and would create new jobs.
- Digitally connected cities need new services delivered through mobile applications. This would result in exponential increase in mobile connections and data usage. The demand will be for Over-The-Top services and mobile applications.
- New demand will emerge in development of video content, video entertainment and video surveillance.
- Country wide Smart city project planning, implementation, and maintenance opportunities. This would involve development and implementation of IoT systems, networking & IT systems, AI, and ML based data analytics platform etc.
- Market 5G ready security cameras would grow.
- Device manufacturers can design advanced 5G chipsets-based products.
- Patient monitoring wearable devices market would grow.
- Business will have opportunities in creating home patient care systems as there will be a favourable transition from hospital care to home care
- Big boost in opportunities for IT companies in implementing data centres, networked infrastructure, and new software application development. There will be a huge opportunity for start-ups in development of advanced data analytics based on AI /ML.

- Opportunities exists for different service provides to collaborate and expand their respective business footprints. For e.g., Hospital will have partner with telecom operators, pharma companies, insurance providers, other healthcare organisations, IT companies etc
- Opportunities for Vehicle manufactures to bring in new designs in connected vehicles, autonomous vehicles, and electric vehicles. This would include passenger infotainment, built-in driver assistance based on 3D imaging and built-in sensors, AR dashboards etc.
- Opportunities for collaboration between vehicle manufacturers, transport providers and telecom operators to bring in new business models to create intelligent transport systems.
- Vehicle data provides a huge opportunity for vehicle makers to monetize by allowing access specific streams of anonymized real-time data to third party developers, as well as the actual application like real-time traffic route guidance, through royalties charged to the third parties.
- Vehicle data analytics could be used for predictive maintenance, usage-based insurance, usage-based tolling and tax, connected navigation services, remote control of vehicles, Driver's condition monitoring service, Emergency call service, Breakdown call service, Stolen vehicle tracking and theft protection, targeted advertisements and promotions, Fleet Management services, Remote vehicle performance configuration and Vehicle usage monitoring and scoring
- Vehicle data could also be used by traffic department to improve traffic systems and prevent traffic congestions, Weather and road condition survey throughout different regions, Disaster management and emergency service providers and third-party vehicle ride sharing providers.
- There would be new opportunities for energy aggregators, who can aggregate various distributed load, generation, and storage of large number of consumers and prosumers. They can remotely monitor, control, and manage the assets in real-time and optimize virtual despatching of distributed resources through data analytics. By optimizing the behind-the meter-assets, they will be able to capture value and monetize. They can ensure that the batteries of Prosumers are charged when the wholesale prices are low. Prosumers can supply energy through the batteries when the wholesale prices are high. Monetizing the behind-the-meter assets is a good opportunity for start-ups who have domain knowledge of energy and have expertise in AI and ML to harness the value of the data.
- There would be opportunities for Energy Services Companies (ESCOs) to provide a broad range of energy solutions including auditing, redesigning, and implementation of energy systems projects, energy conservation, energy infrastructure outsourcing, power generation and energy supply. ESCO could offer end users (prosumers) auxiliary energy services like insights, advanced energy analytics, automatic monitoring, and remote maintenance of energy assets
- New Energy business model could include "**Solar Power as a Service (SPaaS)** "model, where the Equipment provider could install all the required equipment at the Customer premises and charge the Consumer for the electricity utilized, which could be at a much lower rate than the one provided

by the utilities. This business model would be very well accepted by the Consumers as they do not have to invest and maintain the equipment and are able to get power at a lower rate.

- New opportunities will be available for entrants in education field in creating eLearning modules, creating virtual classrooms with AR features, tele-teaching, tele-mentoring, virtual universities etc
- Education institutions could monetize the digitization of knowledge, content, experience, and the skills by delivering it on-line to large number of remotely dispersed students in an interactive manner. They can provide “Anytime - anywhere” on-demand learning. They can track lesson delivery and students’ progress digitally, be able to evaluate the needs of the students in a better way and can also evaluate the effectiveness of the teaching staff more accurately.
- Industries could bring in smart education to reskill/ upskill its employees.
- Big opportunities for content developers to develop and deliver personalised content to individuals.
- Opportunity for gaming industry includes providing a immersive and visually stimulating gaming experience to players by being able to connect with other players in near-real time. It will also provide opportunities for service providers, advertisers, sponsors, and video game producers to develop and monetize new products and services.
- Opportunities for service providers to become integrated smart home providers by partnering with security companies, telecom operators, energy providers, healthcare providers and cable MSOs.
- The biggest opportunity in smart cities would be for M2M/ IoT System Integrators as they services would be required in various implementation of smart city applications.
- Huge opportunities exist from data generated from various smart city applications like smart energy, smart transport, smart health etc. This data could be used for socio economic development of the country.

10.11 Summary

Smart Cities should integrate various isolated city services to provide a holistic view and a central control of all the services. This ‘Integrated Vision” requires good co-ordination amongst various multi-stakeholders in the Smart City eco-system, to make it successful and improve Citizens’ Quality of Life.

The present communication systems are inadequate to provide the target immersive experience like Reliability, Short delay, Device energy efficiency etc which are required for Smart City vision. 5G technologies is essential for the implementation of IoT which forms the backbone of Smart cities and hence becomes enabler to the vision of Smart Cities. 5G will connect wireless networks to billions of devices, such as cars, home appliances, machinery, and wearable technology. Innovative localities will use Smart City technologies like connected sensors and data to provide municipal services more efficiently and effectively. Thereby, 5G will enhance IoT and allow Smart Cities to develop.

5G enables new business models to the City Governance and various smart city service providers. Job opportunities will increase due to the implementation of 5G networks itself and because of the new applications and services being enabled by it, resulting in enhanced economic growth of the city. Jobs in conventional businesses could be impacted by the automation facilitated by 5G. E.g. could be Autonomous vehicles replacing drivers, Automated parking systems replacing parking attendants, Smart Waste Management systems replacing many sanitation workers etc.

5G unlocks the full potential of smart cities. The high-speed broadband access, enabled by 5G, is made easily available to all citizens of the smart city. The design of Smart Cities ensures that all citizens are equally positioned to fully take advantage of new opportunities and enhanced services provided by 5G. Smart Cities enabled by 5G, improves services and quality of living of all residents of the city and enhances economic development.

5G will disrupt value chains and enable new opportunities on an unprecedented scale for a successful implementation of Smart Cities.

The opportunities created include

a) Services and applications for better city infrastructure addressing utilities like smart grids, smart water supply, solid waste management, intelligent traffic management, integrated public transport system, smart street lighting etc.
b) Services and applications for better social and economic well-being of residents including video surveillance and analytics, smart health smart living, smart energy, remote education etc
c) New business opportunities for Telecom operators to become ‘Digital Service Providers’ and offer integrated service offerings, increasing their subscriber base and ARPUs.
d) New opportunities for companies to become ‘Mobile Virtual Network Operator’
e) New opportunities for Energy Aggregators and Energy Services Companies.
f) Big opportunities for IoT and network system integrators and IT organizations.
g) Opportunities for Governments to enhance socio economic development of the city through big data generated from various smart city applications

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11.0 Conclusions and Future Works

The research encompassed many domains of life, which would potentially be impacted by 5G technologies. The author explored the global trends in each of these domains and analysed the market drivers for them. The communication requirements for these services were derived from the market demands and limitations in current communication methodologies were highlighted. Further, analysis was made as to how these requirements can be addressed by the proposed features of 5G. The social and economic impact of the 5G enabled services in all the above domains were discussed in-depth, by exploring new use cases and opportunities. Finally, the innovation required in their Business Models, to harness the capabilities enabled by 5G technologies, were presented

11.1 Sector-wise conclusions

5G has technological advancements which can pave way for new opportunities to be harnessed in every vertical and domain of life. 5G will create a huge market potential for Telecom providers, Transport industry, Healthcare, Manufacturing industries, Power sector, Education sector, Smart Cities, Smart home providers, Safety & Surveillance providers, Content service providers, Enterprises, Businesses, and IoT/ M2M System Integrators.

11.1.1 Telecom Service Providers

Telecom Service Providers business will be deeply impacted by 5G as they must prepare their networks for the scale and flexibility that is required to provide highly cost-effective solutions that support exponential increases in network demand, a wide variety of devices and applications, higher data rates, lower latency, and greater power efficiencies. The classic broadband business model will have to be complemented with new models for 5G focusing on data and video market segments and including greater industry collaboration with Network sharing. The collaboration should include working with niche Mobile Virtual Network Operators. Telecom Operators should move away from being providers of connectivity to aggregators and innovators of third-party offerings transforming themselves into a 'Digital services provider'.

11.1.2 Healthcare Services

Healthcare would be transformed by the advanced features of 5G supporting applications like remote patient monitoring, tele-care and telemedicine, tele-radiology, imaging, smart medication, robotic assisted remote surgery etc. This will have profound social impact as it provides home care to elderly and reduces disparities between urban and rural healthcare through ubiquitous access to health care anywhere, anyhow and at any time. This will also reduce government's spending on Medicare. Business model would shift from volume-based model to value-based care model and home based -care model.

11.1.3 Intelligent Transport System

Intelligent Transport Systems are greatly benefitted by 5G, which brings in superior connectivity to Connected Vehicles, Autonomous Vehicles and Unmanned Air Vehicles. Connected vehicles will help in avoiding vehicle collisions at road intersections and lane merging. Autonomous vehicles will help in eliminating driver fatigue and increases their productivity. Telecom operators play a crucial role in providing the connectivity for this sector and synergy between them and transportation sector is needed to support connected and autonomous vehicles. The development of the Autonomous Vehicles will take connectivity to the next level. We might soon have basic autonomous functions like overtaking, but fully automated driving will not happen until at least 2025. Before then, the industry have a lot of infrastructure to build. This means not just improving traffic light management, equipping highways with wireless technology but adding sensors to monitor pedestrians and most importantly addressing the public fear of driverless vehicles. Connected car will become a reality only when the issues mentioned before are addressed in combination with intelligence inside the car and ultra-reliable connectivity provided by 5G.

The applications enabled by UAVs are expanding to commercial, scientific, recreational, agricultural, and other applications such as policing, peacekeeping, surveillance, product deliveries, aerial photography etc.

The policy environment would be challenging as it involves different stakeholders from different perspectives and need to be flexible.

The social issues and apprehensions could be addressed over a period and Intelligent Transport Systems, enabled by 5G, would become a big success.

11.1.4 Industries 4.0

Industries 4.0 is supported by 5G. 5G supports Industrial Internet of Things, which forms the backbone of Industries 4.0. These features enable the automation of the machinery and processes and brings in flexibility of process scheduling, enhancing the productivity of operations and reduction of costs.

5G enables massive machine type communication, bringing in precision monitoring control and automation. It also enables efficient energy management, reduction of downtimes and associated costs with predictive maintenance. It enables remote control of factories and global connectivity of factories to form a global value chain. Value can be created by smart manufacturing, connected supply chains,

and connected products, quality, and productivity improvements. 5G promises to be a key enabler for 'Factories of the Future', providing unified communication platform needed to disrupt with new business models and to overcome the shortcomings of current communication technologies.
There would be disruption in the current job market as businesses will require less workforce but would need highly skilled digital jobs. Industry leaders and Regulators will have to address the re-skilling of workers to address the social problems.

11.1.5 Smart Energy

Power Sector will see huge benefits by the connectivity provided by 5G which would enable low-cost device connections, leading to detailed coverage of the energy grid. Large number of energy devices can be monitored and controlled in real-time to allow accurate forecasting of power demands, by their integration into the grid enabling load balancing and probable reduction in energy cost to the houses. Outages can be quickly resolved reducing downtime, with predictive analysis. The legacy centralized command and control will make a shift towards a mix of central and distributed control structure, giving more power to the end consumer on the choice of energy consumption and local energy generation. This would enable the hitherto Consumer to become 'Prosumers'. The earlier State-owned monopolies will have to work with multiple generators of energy. 5G features would contribute to smart grid 's new business model enablement. There could be opportunities for a new class of service providers called 'aggregators' or 'virtual power plants', who can aggregate various distributed load, generation, and storage of large number of consumers and prosumers. Value created by data in energy sharing can be monetized.

11.1.6 Education

Education sector would be revolutionised by 5G. The transition from current communication networks to 5G can be exploited in education with increased remote access to multimedia learning, disrupting the traditional way of education by enabling learning anytime at anyplace. It may no longer be only classroom-based system and will enable creation of virtual classrooms with augmented reality features. Teaching will need to adapt to both the physical and virtual classroom. This will bring new definition to Tele-teaching, Tele-mentoring, Virtual university, Virtual classroom, Virtual team-working, etc.

11.1.7 Service Providers, Enterprises, System Integrators

5G will have a great impact on different Service Providers like Smart Home Providers, Safety and Surveillance providers, Content Service Providers, System Integrators, Enterprises and Retail business. The enhanced connectivity and rich communication services of 5G supports Virtual Reality and Augmented Reality applications which has a profound impact on the above services.

Smart Homes will be enabled by the massive and superior connectivity provided by 5G and its support of virtual and augmented reality applications which enables total remote operation of homes and delivery of video rich services leading to Smart living.

Safety of citizens, public and private properties will be ensured by 5G enabled surveillance systems which can provide city- wide video surveillance with predictive analysis to prevent criminal and terrorist acts.

Content service providers will witness a huge growth in their rich communication service offerings, enabled by 5G. The opportunities include optimised media delivery services that meet the different usage patterns for content consumption in different contexts such as provision of real-time UHD content streaming for watching concerts and sporting events from multiple angles, delivery of cloud gaming and video streaming on smartphones everywhere like in high mobility environments such as trains, cars and planes, delivery of 4K-UHD and 8K-UHD expanding to 3D imaging and hologram services over time.

Enterprise digital transformation journey enabled by 5G, includes remote working, virtual collaborated teamwork, simulated trainings, virtual business meetings and moving businesses to the cloud. Retail businesses will be benefitted by the convenience it can provide to consumers through virtual shopping leading to quicker purchasing decisions. Virtual shopping malls with Augmented reality would make on-line shopping the preferred mode of purchase. More connected services could lead to Smart shelves and Smart inventory, which can automatically trigger replacement and replenishments of products going to expire or stock below threshold value. This can lead to full automation with robots handling the warehouses.

IoT/ M2M System Integrators would witness an exponential growth in their businesses, as their services will be required in every domain explained earlier. There will be huge requirement of city-wide sensor network to be built for smart cities. Different players like Telecom Operators can enter this field as they can exert greater control over the end-to-end solution by acquiring IP that will allow them to control applications, software and endpoints. Large System Integrators will have to form partnerships with module vendors and independent app developers.

11.1.8 Smart Cities

The 'Integrated Vision' of Smart Cities are enabled by 5G, which is essential for implementation of massive IoT forming the backbone of Smart cities. This provides a holistic view and central command & control to all the city operations and services. 5G unlocks the full potential of smart cities creating jobs and new businesses. The high-speed broadband access, enabled by 5G, is made easily available to all citizens of the smart city. The design of Smart Cities ensures that all citizens are equally positioned to fully take advantage of new opportunities and enhanced services provided by 5G, improving their quality of life, and enhancing economic development. 5G enables new business models to the City Governance and various smart city service providers for mutual collaboration resulting in greater opportunities for all. 5G will disrupt value chains and enable new opportunities on an unprecedented scale for a successful implementation of Smart Cities.

The opportunities created include

- Services and applications for better city infrastructure addressing utilities like smart grids, smart water supply, solid waste management, intelligent traffic management, integrated public transport system, smart street lighting etc.
- Services and applications for better social and economic well-being of residents including video surveillance and analytics, smart health, smart living, smart energy, remote education etc
- New business opportunities for Telecom operators to become 'Digital Service Providers' and offer integrated service offerings, increasing their subscriber base and ARPUs.
- New opportunities for companies to become 'Mobile Virtual Network Operator'
- New opportunities for Energy Aggregators and Energy Services Companies.
- Big opportunities for IoT and network system integrators and IT organizations.
- Opportunities for Governments to enhance socio economic development of the city through big data generated from various smart city applications.

11.2 5G and Busines Model Innovation

Business model innovation is perhaps the single biggest innovation 5G will bring to the market. We have seen the importance of Data-driven business model innovation in Sec 2.6.2.4. Data is considered as the new oil due to tremendous possibilities it can bring in the business world through predictive and prescriptive analytics. This provides actionable insights to the business owners helping them to develop sustainable business models. We have seen examples of well-known companies which have become successful, due to their data-driven business model innovation rather than their product innovation. Those companies have disrupted their markets or created new markets by using business models designed with the insights provided through data analytics. It has been shown in that sub-section that organisations using big data and analytics within their innovation process are more likely to remain competitive and sustainable. Big data analytics is the driving force of Marketing today. Data is more critical than ever for businesses. Fortunately, new technology like the development of IoT devices and sensors capable of real-time information collection, coupled with advanced analytics technology has made reliance on real-time data practical.

However, for the data-driven business model to remain successful, the requirement is availability of large set of data which can be processed very quickly to get actionable insights. This is where 5G comes into picture. The features of 5G which have been described in Section 2.5.2 like mMTC, uRLLC and eMBB ensures that data is accessible instantaneously. In the subsequent chapters, it has been shown that 5G enables massive high-speed and low-latency connectivity across diverse devices giving rise to new applications. These features make it possible for analysts to collect, clean, and analyse large volumes of data quickly. The big data-at-rest and the data-in-motion can be further translated into real-time insights with actionable intelligence [11]. In the chapter 6, it has been shown how 5G enabled data, supports implementation of Industries 4.0.

5G will make it possible to scale current real-time data collection strategies even further, adding more devices without the need for wired connections or fear of interference. This would enable businesses to scale up their real-time data strategies. Thus, 5G is enabler of data-driven business model innovation which ensures businesses to remain competitive and sustainable.

11.3 Theoretical Model showing how 5G technologies can create a socio-economic impact

The model will fundamentally determine how 5G technology impacts global economy and improves quality of life. The model is characterized by High rate of technology change, broad potential scope of impact, large economic value that could be affected and substantial scope for disruptive social impact.

A] High rate of technology change.

Technology is rapidly advancing or experiencing breakthroughs. Disruptive technologies typically demonstrate a rapid rate of change in capabilities in terms of price/ performance relative to substitutes and alternative approaches, or they experience breakthroughs that drive accelerated rates of change or discontinuous capability improvements.

- Increasing availability of more powerful and cheaper mobile devices and internet connectivity.

- We have seen that 5G enables massive IoT connectivity which gives rise to new use cases and opportunities. Sensor technology is advancing with increasing availability of low cost, low power, and higher performance sensors. There is a price decline of MEMS (micro electromechanical sensors) which is adding to the proliferations of sensor networks.
- Rapid advances in AI and Data Analytics for quicker decision making
- Increase adoptability of cloud technology by companies

B] Broad potential scope of impact

The potential scope of impact is broad. To be economically disruptive, a technology must have broad reach—touching companies and industries and affecting (or giving rise to) a wide range of machines, products, or services. Technology should be capable of being adopted pervasively by multiple industries and domains and It should have transformative capability to change the work process.

Potential scope of impact of 5G is large – all verticals are discussed in thesis. In earlier chapters, the Author has shown how 5G impacts various domains like Healthcare, Transport systems, Energy sector, Manufacturing, Education, Retail, Enterprises, Homes, Businesses, Service Providers like Telecom, Content etc and Cities. He has shown in earlier chapters as to how 5G can transform the work process through automation, remote working, remote education, remote healthcare etc .

C] Large economic value that could be affected

Significant economic value could be affected. An economically disruptive technology must have the potential to create massive economic impact. The value at stake must be large in terms of profit pools that might be disrupted, and capital investments that might be rendered obsolete. It should have the capability to redefine how a competitive economic advantage can be achieved.

5G does have the capability to create a large economic value. It can enable various use cases across industries and other domains, which can enhance economic advantage and improve productivity. It can create new sustainable business models leading to sustainable global growth.
According to IHS Markit [1]

- In 2035, 5G will enable $13.2 trillion of global economic output.
- The global 5G value chain will generate $3.6 trillion in economic output in 2035. This is approx. the combined revenue of top 10 Fortune listed companies.

D] Substantial potential for disruptive social impact.

Technologies that matter have the potential to disrupt social life. They can transform how people live and work. They can bring in conveniences which were earlier unthinkable. They can bring in rapid obsolescence to people's skills in the job market or create entirely new opportunities. This could potentially impact the social fabric of a nation. Overall, the social impact should raise the livings standards of people globally.

We have seen in earlier chapters that 5G does have the potential for this.

- Enhances safety and security, accessibility to healthcare, increased luxury at homes, efficient safe urbanisation, transportation etc

According to IHS Markit [1]

- The global 5G value chain will support 22.3 million jobs in 2035
- Top 10 fortune companies employ 6.5 million workers. For the same output, 5G value chain will support 22.3 million workers i.e 3.4 times as many jobs.

From the above, it can be concluded that 5G would create an effective socio-economic impact.

The Author has considered the following sectors for doing further analysis, as he feels that the impact of 5G on these sectors would be profound and immediate.

1] Healthcare:

As seen in the previous chapters, various international market research companies have stated the economic impact of Smart Healthcare, as follow,

- By 2050 – The population of 60+ people will be 2.43 billion (25% of world's population i.e 9.72 Billion); Out of which 11% are 80+ people, according to UN
- Qualcomm estimates annual global IoT in health care revenues to pass $27 billion by 2025. [3 in Ch 4]
- Healthcare applications itself could have an economic impact of $1.1 trillion to $2.5 trillion per year by 2025 [10 in Ch 4]
- Juniper estimates remote patient monitoring alone to result in cost savings of up to $36 billion globally by 2025 [11 in Ch 4]
- MGI estimates that healthcare will have up to 130 million new jobs fuelled by aging and rising incomes by 2030
- Ericsson estimates telecom operators spend on implementing healthcare at $76 B in 2026
- IHS Markit estimates impact in healthcare of $ 447 billion by 2035 [1].

<u>Author's analysis</u>

Impact of 5G in healthcare results mainly from remote patient monitoring, virtual consultations, and connected ambulances.

Global GDP

Statista reports the global GDP in 2021 is US$ 149 Trillion [2].

Global GDP growth rate @ 3% per year.   Author has calculated the global GDP as $ 168 Trillion in 2025; $ 194 trillion in 2030 and $ 225 trillion in 2035.

Average Global Health spend is approx. 8.2% of GDP. It is higher in developed countries when compared to developing and underdeveloped countries [3].

Taking this account, the average global spend on healthcare in

2025= $ 13.78 Trillion

2030= $ 15.90 Trillion

2035= $ 18.45 Trillion

McKinsey [4] estimates a 2.6 to 3.7 per cent savings in healthcare costs due to disease preventative initiatives. Here, we are looking at 5G data capabilities to provide the preventive strategic benefits.

At the lower figure of 2.6%, 5G data capabilities will provide preventative strategic benefits globally of

$ 358 Billion in 2025

$ 413 billion in 2030

$ 479 billion in 2035

This closely matches with the IHS Markit's estimates of $ 447 billion healthcare impact in 2035.

2] INTELLIGENT TRANSPORT SYSTEMS

As seen in the previous chapters, various international market research companies have stated the economic impact of Intelligent transport systems comprising of Connected vehicles and Autonomous vehicles, as follow,

- 5G Americas estimates that 69 million connected cars to be shipped in 2020. [6 in Ch5]
- 'Secure by Design' estimates 30 million connected cars to be shipped in 2020 and the market for ADAS in US, Europe and China alone to grow to Euro 12.5 Billion by 2022.
- Statista estimates the revenue in connected car market will be over $ 18 billion by 2021 [10 in Ch5]
- Intel and Strategy Analytics in 2017, stated that the economic impact of autonomous vehicles is estimated to be **US $7 trillion** in 2050. [26 in Ch 5]
- Harbor Research expects that the business opportunity value from connected vehicle data is $ 47 billion by 2023[28 in Chap 5]
- McKinsey & Company estimates the overall revenue pool from vehicle data monetization at a global scale to USD 450 - 750 billion by 2030 [29 in Chap 5].
- Council for Science & Technology UK estimates the Socio-economics benefits of Connected Vehicles to UK alone to be 50 Billion Pounds by 2030 to 900 billion pounds globally by 2025. [30 in Ch 5]
- Frost & Sullivan (2017) predicts that more than one trillion USD can be added to the industry revenue pool by 2030 [31 in Ch 5].

- The economic impact of drones in military applications alone is estimated at between $ 20 – 127 B by 2020 by YES Global Institute {27 in Ch 5]   and its adoption by consumers will increase 4 to 6 times.

Author's analysis

Global GDP

Statista reports the global GDP in 2021 is US$ 149 Trillion [2]

Author has assumed a global GDP growth rate @ 3% per year.

With this assumption, Author has calculated the global GDP as $ 168 Trillion in 2025; $ 194 trillion in 2030 and $ 225 trillion in 2035.

i) Traffic Congestion Costs

Different regions have different traffic congestion costs against their GDP.

Europe has 1%; US has 2%, Asia has 2% to 5% as it is densely populated with countries India, China, Thailand, Indonesia etc [5].

Author has assumed a traffic congestion at 2.25% of GDP, based on figures in various regions.

With this, the traffic congestion costs are calculated as:

- **$ 3.78 trillion in 2025**
- **$ 4.37 trillion in 2030**
- **$ 5.06 trillion in 2035**

The introduction of technologies with 5G and IoT is expected to bring a benefit of 10% of the total congestion costs, and savings which can be attributed to 5G alone is 5% [6].

This amounts to a

Globally, 5G data capabilities will provide traffic congestion reduction benefits of

2025= $ 189 billion annually

2030 = $ 218 billion annually

2035 = $ 253 billion annually

B] Road accidents costs

According to WHO, approx. 1.35 million people are killed every year inroad traffic crashes.

Road traffic crash cost are 3% of GDP

Author has calculated the road traffic crash costs as:

2025-- $ 5.05 trillion

2030 = $ 5.82 trillion

2035 = $ 6.75 trillion.

The introduction of technologies with 5G and IoT, is expected to bring a benefit of 10% of the total congestion costs, and savings which can be attributed to 5G alone is 5%

This amounts to a

Globally, 5G data capabilities will provide road traffic crash cost reduction benefits of

2025= $ 252 billion annually

2030 = $ 291 billion annually

2035 = $ 337 billion annually

The total benefits from 5G, considering reduction benefits in traffic congestion and road crashes are:

2025= $ 441 billion annually

2030 = $ 509 billion annually

2035 = $ 590 billion annually

This closely matches with the IHS Markit's estimates of $ 627 billion impact in Transport sector in 2035.

3] <u>Smart Utility Meters – Electricity/ Gas/ Water</u>

As seen in the previous chapters, various international market research companies have stated the economic impact of Smart Energy, as follow,

- Global market for smart grid tech by 2020 = $ 75 Billion [2 in Ch 7]
- Global market for smart grid tech by 2021 = $ 65.5 B [3 in Ch 7]
- Global market for smart grid tech by 2022 = $ 84 B growing at CAGR 13.2% [4 in Ch 7]
- Global Smart grid security market == $ 10.58 B by 2025 @ CAGR 10.5%

Smart Meters with embedded 5G capabilities will provide easier access to data and real-time information. According to study conducted by European Commission [6], 5G data capabilities in smart meters will give benefits:

a) Increase strategic benefits for utilities by Euro 20.75 per meter
b) Increase operational benefits in utilities by Euro 9.81 per meter
c) Provide benefits to customers by Euro 10.7 per meter.

Total benefits due to 5G is estimated at Euro 22.71

Therefore, Total benefits due to 5G capabilities / Smart Meter = US$ 26.82

According to IoT Analytics [7], global Smart Meter shipment between 2019- 2024 is growing annually at 7%. and is expected to exceed 200 million annually by 2024.

According to a Global Smart Meter report by Wood Mackenzie in Jul 2019 [8], the global smart meter installation will exceed 1.2 billion by 2024.

Taking potential benefits of 5G as US$ 26.82 per Smart Meter, we can see an annual benefit of $ 5.36 billion annually amounting to $ 32 billion in benefits by 2024.

11.4 Limitation of analysis

The Author has made the qualitative analysis and brought in the use case recommendations based on the features portrayed by 5G during 2013. The successful implementation of the use cases presented can only happen when the technology is mature with spectrum availability and all the projected features are actually demonstrated. There could be areas which the Author has not been able to get the right answers, as the live trials might not have been done. He has made his analysis based on the method of data collection which he has listed in Section 1.7. Also, the Author might not have been able to address some domains in this thesis, which might potentially be impacted by 5G. These are mentioned in Sec 1.7.5 "Limitations of Study".

11.5 Challenges in 5G implementation

5G networks would be built using large number of small cell networks and would involve 100 to 1000 times more antenna locations than 3G/4G networks. These would be very much smaller in size and could easily be installed on light poles, traffic signal posts, bus shelters, and on buildings. This large number of small sized antennas would easily handle the exponential connectivity needs in Smart City. The advantages of the small cells are that they can provide custom-designed special services to different verticals like transportation, public safety, healthcare etc. The benefits of 5G deployment in terms of the opportunities provided, are huge. However, the cost of implementation also must be considered.

Author envisages the following challenges in 5G implementation:

- The current 3G/4G infrastructure consists of smaller number of tall telecom towers which provide coverage for large distances. Site acquisition, rental costs. fees and the regulatory approval processes for these towers have been streamlined and standardized over a period of time. These processes may not be appropriate for 5G deployment and may require some period of time for the new processes to get implemented, accepted and standardized
- Due to the exponential increase in number of site installations, it takes more effort and time for each site acquisition and approval. Telecom Operators would have to identify and work with a large number of 'site landlords' to get hold of the sites. The larger number of antennas needed would need more installation effort. This would increase the cost of implementation even though it would provide more job opportunities.
- The approval process for deploying network infrastructure would involve complex procedures and time consuming. The regulatory authorities are used to certain fees and approval cycles for the larger 3G/4G towers and they may try to apply the same for 5G also. Approvals for each small cell implementation could take up longer periods like the approval cycle time of one large macro cell

tower. This would pose a great challenge to the Telecom Operators as they must wait for the approval of the complete lot of small cells in each area, to be truly operational.

- The regulatory approval processes are different in each country. Even in each country, approval process would vary from each city and their municipalities. There could be multilevel approvals required from different government agencies for each installation. This would add more delay and cost for getting approvals. Also, the license fees would need to be negotiated with the regulatory authorities, as there could be a possibility that they may consider each 5G small cell installation on par with the normal tower installation. Otherwise, it would be financially unviable to implement such a large number of small installations.
- Apart from the above challenges, there could be many more in terms of competing Telecom Operators. Every Telecom Operator would want to acquire all possible sites for small cell installations. This could result in unhealthy competition. In present 3G/4G, such issues have been ironed out with many Operators sharing the same large macro-tower.
- Also, the physical security of the small cell installations would be a great concern. It may be very difficult to monitor and control large number of installations. There could be thefts or pilferage of the antennas and even destruction of sites. The current smaller number of macro towers were easier to maintain from the security angle.
- Other challenges include spectrum acquisitions which is a huge cost and the technology expertise and resources required for this.
- A very good backhaul network is required to meet the throughput and the latency expectations of 5G. This may not be available across entire geography of large countries and in developing countries. For e.g. India has about 1.5 million Kms of fibre deployed with less than 25% of the telecom sites connected through fibre [9].
- Industry may need huge additional investments for the spectrum and network densification needs and this could slow down full-scale deployments. Operators may want to tread cautiously until they are confident in return on investment. Department of Telecom, Govt of India, feels that 5G launch might get delayed as the expected capital expenditure investment of $60-70 billion needed for 5G, could be a challenging factor [10].
- Cyber security and privacy protection would be challenging as huge number of interconnected devices are involved.

The above challenges could pose a delay in Telecom Operators implementing 5G technologies, as they would want to have a clear understanding of the return on investment, before embarking on this journey.

11.6 Policy Recommendations

11.6.1 Standards & Inter-operability

High level of inter-operability among different types of devices across public and private networks are required. In addition, interfaces need to be highly secure. This will require international standard setting. Governments will need to cooperate on matters of international law, regarding intellectual property, liability, and other issues that span borders. Governments should setup their country specific standards development organisation to represent their country in International Standards organisations like 3GPP, ITU, IEEE, IETF This organization should be represented be academia, industry associations and telecom operators, with a strong commitment to influence and include the country specific requirements in International Standards. The standardization activities of 5G is discussed in Section 2.7.1.1.

5G Centre of Excellence and Interoperability test labs should be opened by Government with association from academia and industry. This should provide a platform for users to experiment with different use cases and test equipment for interoperability at a reasonable cost. Application developers and start-ups should be able to use this for developing innovative applications

11.6.2 Spectrum

Radio spectrum is a scarce resource, and spectrum policy is key to enable cost effective and quality wireless services. 5G applications have different spectrum requirements in terms of frequency range (low, high) and size (wide, ultrawide). Methodology for arriving at spectrum needs, requires consideration of multi-operator deployment environments, inter- and intra-network interference considerations, frequency reuse, need for multiple carriers and radio interface capabilities. Continued growth of data and video, demands more spectrum. Variety of spectrum is needed for different use cases

Different licensing aspects of 5G spectrum are licensed, unlicensed and shared with incumbents.

Regulatory frameworks for the available mobile communication bands need to be reviewed and new frameworks need to be established for 5G NR deployment in new frequency bands. These frameworks should facilitate innovation by removing any potential barriers to the introductions of key 5G innovations.

New local licensing models will be needed to complement existing models to allow different stakeholders to establish local 5G small cell radio access networks with guaranteed quality. Spectrum assignment and sharing is important in a 5G context to determine who can use 5G bands. Specific spectrum access regulations need to be made available for local 5G networks who are serving vertical industries. Licensing models should enable easy establishment of small 5G networks. Regulation should encourage competition to enable Micro-operators to serve specific local verticals independently and encourage innovation by making spectrum available at reasonable costs which is important to accelerate deployment of 5G across different verticals. 5G Micro Operators would offer various services in their local areas for specialized use cases in different verticals. This would need micro licensing, where the regulators must develop suitable procedures for awarding micro licenses to the local micro operators including new operators. This has the benefit of allowing new innovative smaller players who could address specific verticals in local markets efficiently.

11.6.3 5G Infrastructure deployment policies

Regulatory policy support is very important for deployment of 5G. As seen in the earlier section, 5G requires large addition of active and passive infrastructure. These includes towers, antennas, ducts, backhaul radios etc. Implementation of this requires 'Right of Way' and a uniform policy framework formulated and controlled by the federal government. This framework should be uniform across the country and should be enforced in all States and local governments uniformly.

There should be improved right of way permit approval process involving on-line applications, single window clearances and time bound permit decisions. The fee structure should be relaxed considerably for the small cells as compared to large towers. The framework should also allow usage of utility resources like lamp poles, traffic light poles, public places etc, for installation of small cells. 5G deployment in urban areas need small cell densification. Hence, the approval for one lot of small cells in each area should be given rather than approving each cell installation separately.

5G will also be deployed for services within buildings. It is important that provisioning of 5G infrastructure be mandated in building plan approvals for large multi-dwelling units and office buildings. Policy framework should also have guidelines for active and passive infrastructure sharing, which can bring benefits of cost sharing. There should be provision for physical security of infrastructure of the high density 5G networks, as there could be possibility of thefts or sabotage. Guidelines should focus on real time protection of infrastructure components

11.6.4 Data Governance Framework

In the earlier chapters we have seen the importance of data-driven business model innovation. The availability of large amount of data fuelled by 5G connectivity is the catalyst for data-driven business model innovation. Big data, analytics and AI have the power to transform existing business and create new opportunities. The author recommends Governments to create frameworks to enable and regulate all aspects of data consisting of both personal and non-personal data. Those data without any personally identifiable information is considered as non-personal data. Examples of non-personal data could be data on weather conditions, sensor data, data from public infrastructure etc. Also, initial personal data which has been anonymized, can be considered as non-personal data. Non-personal data anonymized from sensitive personal data may be considered as sensitive non-personal data. Public non-personal data could include anonymized data of land records, vehicle registration, public health information.

Private non-personal data could include those which are derived from private effort. These frameworks should treat data as an asset so that it can be monetized directly by trading it or building a service on top of the data. The value of data could be determined by its usage i.e. how frequently it is being accessed and the number of people accessing it. Higher usage of a data, greater can be its value. Also, the extent to which the data could advance a company's business, could be a measure of its value. During a company's merger of acquisition, its data should also be treated as am intangible asset. The framework should define personal and non-personal data so there should not be any ambiguity in their usage.

Privacy and data protection policies should ensure that consumers are protected from security vulnerabilities, reidentification of anonymized data or from derivation of personally identifiable insights from non-personal data. Government should regulate availability of data access so that smaller companies and start-ups are able to get access to real time data. The non-personal data may be used by entrepreneurs, researchers, academia, and governments to develop new innovative products/ services which can be beneficial to the society at large.

The policy should ensure openness in some anonymized data that can be made public for development of socially relevant works. This is very important to develop accurate data models to harness the advantages provided by data-driven business model. The framework should ensure that 'data monopolies' are not created which could lead to imbalances in bargaining power of few companies. The framework should ensure a level playing field. Also, adequate protection for IP rights so that new business creation can be safeguarded. Governments would also need access to data for delivery of public services. The framework should include data sharing such that community data is available for social and public purposes.

Finally. policy framework should mandate cyber security audits.

11.6.5 Intelligent Transport System Policy

Autonomous vehicles Policy - Regulators should allow driverless vehicles usage only after getting public mandate through a poll. If public is OK with the autonomous vehicles, Regulators should develop standards and regulations with respect data privacy and safety with respect to them. The policy environment would be complicated as it involves many different stakeholders from different perspectives. Policies need to be flexible to realize the benefits of ITS. Regulators should bring an integrated policy and legislation to address this. There are many policies addressing Public safety, Smart Cities, Transportation, Road Traffic, Air Traffic etc which address individual areas. As ITS has relevance in all of these, Regulators should bring an 'Integrated Intelligent Transport System' policy covering connected commuting, autonomous vehicles and UAVs, addressing public safety, vehicle to everything integration, security, flight restrictions, no-fly zones, emergency response etc. Convergence of transportation, communication and public safety policies are required. Also, Government should bring out clear legal provisions on the accountability in case of accidents.

Drone Policy – Drone policies should describe the ownership, restricted and no-fly zones, usage, and applications. It should address the public safety to ensure that it does not crash into public places, especially in densely populated areas. The policy should national security due to the possibility of its usage in spying and terrorism.

11.6.6 Industrial Policy

For accelerating industrialization, Governments should implement comprehensive framework for the conceptual and structural design of Industry 4.0 systems. They should bring industries, academia, trade unions, trade associations etc together, partner with International Standardization bodies like Industrial Internet Consortium/ ISO/ OEC/IEEE/ ITU-T etc to arrive at a common reference model

Safety regulations --Industries 4.0 concept depends on autonomous devices and machines. Problems can arise due to malfunction of these autonomous devices and machines which can cause damage and injuries to personnel. Here, we are not looking at faults created by human error but those caused by machines which are working autonomously. Governments should introduce strict safety regulations which should also address liability issues. The owner of such autonomous systems should be responsible and liable for any damage caused by the system. It can be expected that, as a greater number of autonomous systems are developed and used, more laws and regulations will need to be written to establish a strict liability on owners of such systems. Cyber-attacks on the intelligent machines, could make machines behave erratically and may lead to material damage and worker injuries. Regulations should ensure that strict cyber security measures are put in place.

11.6.7 Employment Policy

Government policies should address the job displacements created by automation, by mandating employers to upskill/ cross skill existing workers to minimize the impact of job displacements. Also, policy should include incentives for increased investment in human capital and skills to enable industrial transformation. The policy should also provide income and transition support to displaced workers. The Education policy should ensure that teaching is continuously updated and relevant to future job needs. Innovations in teaching methods should be introduced in education systems.

11.6.8 Investment Policies

Service providers will have to put in huge investments for bringing in new business models and will have taken big risks in getting return on investments. Governments should offer a comprehensive support package to enable quick deployment and mitigate risks. Governments could declare 5G networks as an

essential infrastructure for the development of country and provide access to capital at lower costs. Public private partnerships should also be encouraging for 5G deployment.
Government should encourage 5G trials to prove all use cases, by providing required support. Support may include making spectrum available free of cost for trials for a fixed duration. The operator should be given the opportunity to purchase that spectrum after successful trials. Financial support in terms of special subsidy may also be given to encourage trials

11.7 Global adoption of 5G - Race towards domination

Technological advances towards 5G along with greater industry consolidation, will transform network economics. This is one technology that has created so much of excitement in the world, like none before. The author has tracked global Technology companies, global Standard bodies, academia, research organisations, businesses, various Governments, major global events, statements of global industry leaders etc and seen the excitement about 5G and the special focus given to it by all of them. The author has substantiated this by researching and documenting the status of 5G global deployment in Chapter 2.7 "Current State of 5G global deployment", where he had written about the fierce competition globally in 5G domain. He had listed the Standardization, Spectrum and Regulation policies for 5G in Section 2.7.1. He had described the readiness of global technology majors in Section 2.7.2 in which he had described the developments at Ericsson, Nokia, Samsung, Huawei. He had further described in subsequent subsections, the 5G deployment scenario in Asia (covering South Korea, China, Japan), Europe (covering UK, Finland, Norway, Sweden, Germany, Switzerland and Russia), USA, Australia and India.
Adding to the above, Author has listed below some of the statements of global leaders expressing their concerns, confidence, and excitement about 5G:

- World leaders of global government and industry at the World Economic Forum 2020 discussed on a theme on cohesive and sustainable world and the focus of the discussions were cantered on the benefits of 5G [12],[13].
    - Qualcomm EVP and General Counsel made a statement "5G will change our world" and added that the potential 5G use cases as infinite.
    - Ericsson's SVP mentioned that the intersection of 5G and IoT as key future drivers of the digital economy contributing to corporate and civic sustainability and mentioned that the economic value being generated could be between \$3.9 trillion to \$11.1 trillion a year by 2025 and further that 5G is powering the Fourth Industrial Revolution in the same way that steam, electricity and silicon powered the previous three.
- World Economic Forum white paper released in Jan 2020 on the "Impact of 5G- Creating new value across industries and society" [13] concludes that

    - Economic value at stake is significant and the job creation potential is large
    - 5G will primarily contribute to industrial advances driven by use cases.
    - 5G has the potential to provide quality internet access to geographical areas that are currently underserved by the telecommunications network. This could unlock significant social impact through use cases related to tele-education and telemedicine.

- During a CEO Forum discussion before pandemic in USA, top CEOs stated the importance 5G in Telehealth, remote education, and security. CEO of Sentara Healthcare, a recipient of the Transformative CEO award in Healthcare 2019, talked about the benefits of 5G in telehealth. Group CEO of Verizon Business brought in the importance of 5G in education. The CEO OF Thyssenkrupp felt that 5G brings in better data security. Overall, the CEO forum concluded that 5G would bring in endless possibilities. Covid-19 pandemic has brought in an increase in the need for telehealth, remote education, remote working, all them requiring robust connectivity. These were anticipated before the pandemic itself [14].
- In a recent interview by Fortune with the CEOs of Cisco and Qualcomm, both were optimistic about 5G and mentioned that 5G has already made a mark in the post-coronavirus world by teleconferencing, telemedicine. Both concluded that 'work from home' will be the normal post covid19. Qualcomm CEO mentioned that productivity has increased because of 'work from home' and Covid19 has made the use case for 5G. He mentioned that the question of 'why 5G?' is not relevant anymore as the necessity has become obvious. Governments will have to prepare for the pandemic by investing in telemedicine, remote education, secure connections between people and enterprise. [15].
- Qualcomm President stated that the nest transformation of the economy will be built on top of 5G foundation [16].
- India has announced that it will advance its Digital India vision from 5G. The special 5G High Level Forum setup by the Government with senior business and government leaders, have brought in all the benefits that 5G would bring to India in their report "Making India 5G ready".
- The Defence Innovation board of US has stated that the leader of 5G stands to gain hundreds of billions of dollars in revenue over the next decade, with widespread job creation across the wireless technology sector i.e the country that leads in development and deployment of 5G will see more economic growth and will have more power. This is the reason for the race towards 5G and is where all the excitement. China sees technological dominance to become world superpower and has taken giant leaps in fostering 5G. The outcome of the 5G race is likely to determine whether the US will continue to maintain its technological edge and shape geopolitics for the next couple of decades or if it will cede that control to China[17].

- The race towards 5G deployment is happening. Arthur, contributor at Forbes [18], states that "country that dominates 5G, will dominate the world". Countries that want to stay competitive in the global economy are adopting 5G increasingly at a rapid pace. Telecom operators and Technology providers around the world are investing in the trials and are looking at its early commercial deployment.
- Author has tracked the initiatives of the OEMS and the countries across the world in Sec 2.7. Leading technology vendors are Huawei (China), Ericsson (Sweden), Nokia (Finland) and Samsung (S.Korea). Huawei has the highest market share globally. Various countries, global telecom OEMs, telecom operators, automobile manufacturers, healthcare providers, smart city planners and integrators, energy companies, manufacturing industries, technology integrators, AI/ML/ big data developers etc, have proactively taken steps to harness the capabilities like never before. These are described in earlier chapters. Countries like India, which used to be laggard in adopting any telecom technology, has also taken this on highest priority at the very top policy level and have taken steps to be an early adopter.
- Author lists the ideal benefits that countries would be looking for, as below:
    - Bring full benefits of 5G to the people and economy at the lowest cost and at the earliest. To keep cost low – they must keep competition high and equipment cost low.
    - Ensure that there are no national security risks due to the critical telecom infrastructure.
    - Countries having IP in 5G could monetize them.
    - Countries which have limited IP, can create opportunities through 5G deployment services and value creation like developing use cases in domains addressed in this thesis
- Author considers the investments being made by various countries to the benefits that they derive out of 5G. The investments could include the cost of development and implementation. The benefits could include economic value in terms of 5G enabled output or social value in terms of 5G-enabled employment.

According to Market research firm IHS Markit [19], 5G would contribute to

- $13.2 Trillion potential global sales across multiple industry sectors and
- 22.3 million job generation by 2035.
- The 5G value chain $ 3.6 T from technology forms like Telecom OEMs, Network Operators, Infrastructure equipment manufacturers, content & application developers.
- The 5G value chain will invest an average of $235 billion annually to continually expand and strengthen the 5G technology base within network and business application infrastructure
- USA and China would be leading almost equally in investments and would together form more than half of the world's investments in 5G. China would lead in generation of 5G-enabled output ($ 1.3 trillion) followed by US ($ 0.786 20 Trillion). In terms of employments generation, China would once again lead with 10.9 million whereas it is 2.8 million in US.

- Author feels that China has an initial edge over US with their own technology, a large domestic market and their current lead in the global scene. USA does not have their own telecom technology, but still can compete due to their investment capability and a large domestic market. China is rapidly deploying 5G internally and will have half a million towers by end of 2020. It has a goal of 5 million towers which could enable faster connectivity to hundreds of millions of its people. New Chinese companies are coming up to make devices and other systems to monetize the use cases of 5G. [20]]20]
- Even though China is leading the 5G game, global political situations, may ban Huawei from selling in many countries and this could be a challenge for Huawei in the race. Government across the world have considered this as a national priority. Recently, heads of many countries, like US, UK and Australia have banned Huawei from participating in 5G trials / deployment citing national security concern. All countries may not join this ban, especially South east Asian countries like Thailand, Indonesia, Myanmar, Cambodia, Philippines, Malaysia etc have agreed to use Huawei technology due to their low prices compared to their European competitors. They are not much concerned about the security threat from Huawei like some of the advanced countries. Also, domestic market itself is huge for Huawei. Asia could hold the key to 5G dominance [21].
- The Author feels that along with the deployment of 5G network which is the race today, countries will need to work through the outcomes that is wished to be delivered, the sustainable use cases that will deliver these outcomes and the data and analytics expertise required to support those use cases.
- The awareness, understanding and the importance given to this technology by the Heads of advanced countries has never happened before. Most of the technology conferences world over, are focussed on 5G related topics. Leading technology companies like Intel [22], Qualcomm [23] etc have considered 5G as one of their main focus areas. 5G topics have become the most popular in all World Economic Forum meetings at Davos, where CEOs of top companies around the world are discussing it [24] [25] [26]. Of course, 5G is the main topic at Mobile World Congress. The author has been tracking global news on 5G daily and it is just humungous and has never seen any earlier technologies like 1G through 4G-LTE create this kind of interest and excitement at highest levels of Governments, academia, and businesses.

11.8 Future research

As 5G standards evolve and live trials are conducted, new use cases can be explored in the vertical domains addressed in this thesis. Also, research can be done on new domains which can be impacted.
Multi Business Model Innovation needs to be explored in all the domains discussed in the thesis, for better monetization and benefits to all stakeholders.

There will always be on-going demand for higher speeds and larger data, both from business and consumers. This will pave the way to the requirement of features beyond 5G, maybe a decade from now. Industries 5.0 is evolving, where humans are expected to work along with machines, and this may demand much superior communication features.

Once, 5G capabilities are fully harnessed, it is required to research as to what new opportunities can arise with features which are more superior to 5G. Future research can be done on the global socio-economic impact of the proposed features of technologies beyond 5G, as they evolve. This could be 5G to Satellite connectivity, Human Bond Communication, Mind to Mind communication, or could be combination of all of these. It could form a framework of a fully connected world of low-cost, extremely high-speed internet service with the ability to tap satellite communication networks. It should provide a fully integrated system consisting of cellular communications, space-and –air-based communications, wireless local and broadband based communication.

Future research work needs to be done to enable these applications (wish list):

- Industries 5.0 – to enable humans to work along with machines.
- Applications utilizing all 5 senses -Sight (Optical), Hearing (Aural), Smell (Olfaction), Taste (Gustation) and Touch (Tactile). Examples of such applications could involve smell (e.g., types of smoke, air pollutants), tactile information (e.g., surface roughness, wind speed), taste (e.g., liquids) and learning about an object or its surroundings as in hazardous material handling, surveillance etc.
- Collaborative teamwork – Product design team working across different geographies arriving at co-ordinated product designs
- Virtual meetings/ parties with remote family and friends, with ability to interact on an emotional level.
- Seamless provision of services provided everywhere including remote areas, on-board ships, aircrafts (in-flight services), moving trains etc.
- Vehicle crash avoidance and next level of Autonomous vehicles.
- Ability to be able to control appliances with gestures.
- Ability to interact with people without having language barriers – with mind-to-mind communication or 'Telepathy'.
- Communication between devices, processes and objects [27].
- Total automation of manufacturing technologies.

Prof Ari Pouttu of Oulu University, has stated that the millisecond latency provided by 5G, is not sufficient for some time critical applications and further enhancement of the communication capability is required [28].

Future research should enable:

- Ultra- fast edge connectivity
- Ultra-Low latency or real time connectivity
- Super IoT – unlimited connected devices
- Integration with Data and AI to get insight from data situation context leading to smart operations.

Increased adoption of IoT will put more pressure on the network to look beyond 5G. The massive increase in the amount of data will require networks to operate in higher frequencies going towards terahertz. Advances in AI, materials and antenna would pave the way for further design improvements in the network. Research is needed on future generation of networks working on tera hertz speeds and integration of AI /ML into an intelligent network system

Future research directions should consider the following:

- 5G to Satellite connectivity
- Human Bond Communication
- Mind to Mind communication
- 5G Test Beds to be continually evolved to meet the growing requirements.
- Terahertz radio technologies
- materials and antennas to be utilized in future for circuits and devices.
- Multi-access Edge Computing – The integration of Artificial Intelligence (AI) algorithms and machine learning at the edge of the networks to further assist the data-intensive requirements of the IoT applications. This could be vital in autonomous vehicles. Also, interactive AR and VR technologies could be researched on MEC sites**.** This could find applications in autonomous driving, air-traffic control, telesurgery etc [29].
- Predictive and Prescriptive Data analytics - 5G is expected to enable use cases which are very data intensive and needs actionable insights in near real-time. For this to happen, work has to be done to develop predictive and prescriptive data analytics capabilities

6G is a popular term used in the industry for looking beyond 5G. Few research organisations are already moving in that direction. University of Oulu (Finland)'s "6Genesis - 6G-Enabled Wireless Smart Society & Ecosystem" project is the world's first to start research on 6G [27].

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APPENDIX A – Global Organisations working on Healthcare Standards

Some of the global organisations working on development of communication standards in healthcare are as below:

1. ITU-T (International Telecommunication Union) - ITU-T has been working on e-health standardization from the perspective of general ICT infrastructure, such as future networks, multimedia, biometrics and security. It is Focus Group on M2M Service layer looks at the requirements and specifications for a common M2M service layer with initial priority on e-Health and network capabilities for e-Health monitoring services. The Focus Group has partnered with other stakeholders like Continua Health Alliance and World Health Organisation
2. Continua Health Alliance - More than 200 global healthcare and technology companies have joined to form this alliance, with the objective of improving the quality of personal healthcare by establishing inter-operability in personal connected health systems. This alliance has become member of ITU. Continua has published design guidelines which is approved by ITU-T and is named as the ITU-T H.810 Continua Design Guidelines, which has become the Industry standard now.
3. Personal Connected Health Alliance (PHCA) – is a coalition of different stakeholders to realize the full potential of personal connected health. Its members include global life sciences, technology and early stage companies, along with government and academic institutions. This alliance promotes adoption of the Continua Design Guidelines [1].
4. ISO Standards EN 13606 Electronic Health Communication (EHRCOM) – Handles Medical Devices
5. Health Level 7 (HL7) – Health Level Seven -Standard for exchanging information between medical applications, allowing healthcare organisations to easily share clinical information. They define a framework for the exchange, sharing, integration and retrieval of electronic health information. This framework is widely used globally and support clinical practice and total management of health services [2].
6. DICOM – Digital Imaging and Communication in Medicine (DICOM) Standard for exchange of images and related information. DICOM is the most widely followed image messaging standard globally and is adopted in radiotherapy devices like X-Ray, MRI, Ultrasound and cardiology imaging and ophthalmology as it enables exchange of medical images with the quality and accuracy required for clinical use.

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APPENDIX B – Rao, Sriganesh K – Resume

Sriganesh Rao received his B.E (Electronics) degree from Bangalore University (India) in 1980 and MTech (Electronics) degree from Karnataka Regional Engineering College (Now renamed as National Institute of Technology, Surathkal) of Mysore University, in 1983 followed by MBA (Technology Management) of Deakin University, Australia in 2000 with focus on International Telecommunication Management.

He is an ICT Professional with over 34 years of global experience in leading complex technology projects in Australia and India, with rich background in Business Development, Engineering, Program Management and QA in Telecom, Government & Defence verticals across Embedded, Engineering Services, Testing and Manufacturing horizontals.

His experience spans across leading IT organizations like Tata Consultancy Services & IBM, Telecom Service Providers like TATA Teleservices & C&W OPTUS (Australia), Telecom OEMs like Bharat Electronics, United Telecoms & ERG (Australia) and Telecom OSS/ BSS Providers like Alopa Networks. At present, he is employed at Tata Consultancy Services, Bangalore (India) working in Telecom domain. He has handled Business development and Pre-sales Solutioning in Telecom, Media & Entertainment, Government, Defence & Aerospace market segments and also led strategic initiatives in new technology areas –IPv6 and M2M/ IoT for India business and handled very large Telecom tenders as Bid Director. He has also worked on planning the customer experience management of broadband network at National Broadband Networks, Australia.

His previous professional experience highlight includes

- Handling nation- wide broadband roll out planning at Tata Infotech, a large IT system Integrator in India.
- Responsible for Broadband new product initiatives at Tata Tele Services, a Telecom Operator in India
- Responsible for Quality Assurance of Broadband Software product development at Alopa Networks, India
- Broadband Engineering at Cable & Wireless Optus, Australia
- Test Automation development of Telecom products at ERG Telecommunications, Australia
- Failure analysis of Servers at IBM, Australia
- Engineering development at Tata -IBM in India
- Test Automation development of Computer peripherals at TVS Electronics, India
- Test Automation development of Telephone exchanges at United Telecoms, India
- Test Automation development of defence communications systems at Bharat Electronics, India.

He has worked closely with Government of India’s initiatives in the Standardization activities in Machine to Machine (M2M) / Internet of Things (IoT). As the Chairman for the Dept. of Telecom’s (Govt of India) “M2M Gateway and Architecture" Workgroup he has contributed to the preparation of “National Telecom M2M Roadmap”. Currently, he is Member of the National Working Group -20 on the subject of “IoT and its applications in Smart Cities and Communities”.

He is a Senior Member of IEEE, Senior Member and Certified Professional of Australian Computer Society and Life Member of Computer Society of India. His current interests include 5G, M2M, IoT, Smart Cities, Industries 4.0 and Business Model Innovation.

APPENDIX C – Mandatory Declaration

HAS BEEN ATTACHED SEPERATELY

APPENDIX D – Co-Author Statement

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Declaration of co-authorship*

Full name of the PhD student: Sriganesh Kamasamudra Rao

This declaration concerns the following article/manuscript:

Title:	Impact of 5G Technologies on Industries 4.0
Authors:	Sriganesh K Rao, Ramjee Prasad

The article/manuscript is: Published ☒ Accepted ☐ Submitted ☐ In preparation ☐

If published, state full reference: Springer Wireless Personal Communications, 100(1), 145-159
DOI: 10.1007/s11277-018-5615-7

If accepted or submitted, state journal:

Has the article/manuscript previously been used in other PhD or doctoral dissertations?

No ☒ Yes ☐ If yes, give details:

The PhD student has contributed to the elements of this article/manuscript as follows:

A. Has essentially done all the work
B. Major contribution
C. Equal contribution
D. Minor contribution
E. Not relevant

Element	Extent (A-E)
1. Formulation/identification of the scientific problem	A
2. Planning of the experiments/methodology design and development	A
3. Involvement in the experimental work/clinical studies/data collection	A
4. Interpretation of the results	A
5. Writing of the first draft of the manuscript	A
6. Finalization of the manuscript and submission	A

Signatures of the co-authors

Date	Name	Signature
10-04-2018	Ramjee Prasad	Ramjee Prasad

In case of further co-authors please attach appendix

Date: 10-04-2018

Signature of the PhD student

*As per policy the co-author statement will be published with the dissertation.

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Declaration of co-authorship*

Full name of the PhD student: Sriganesh Kamasamudra Rao

This declaration concerns the following article/manuscript:

Title:	Impact of 5G Technologies on Smart City Implementation
Authors:	Sriganesh K Rao, Ramjee Prasad

The article/manuscript is: Published ☒ Accepted ☐ Submitted ☐ In preparation ☐

If published, state full reference: Springer Wireless Personal Communications, 100(1), 161-176
DOI: 10.1007/s11277-018-5618-4

If accepted or submitted, state journal:

Has the article/manuscript previously been used in other PhD or doctoral dissertations?

No ☒ Yes ☐ If yes, give details:

The PhD student has contributed to the elements of this article/manuscript as follows:

A. Has essentially done all the work
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4. Interpretation of the results	A
5. Writing of the first draft of the manuscript	A
6. Finalization of the manuscript and submission	A

Signatures of the co-authors

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Declaration of co-authorship*

Full name of the PhD student: Sriganesh Kamasamudra Rao

This declaration concerns the following article/manuscript:

Title:	Telecom Operators' Business Model Innovation in a 5G world
Authors:	Sriganesh K Rao, Ramjee Prasad

The article/manuscript is: Published ☒ Accepted ☐ Submitted ☐ In preparation ☐

If published, state full reference: River Publishers –"Journal of Multi Business Model Innovation and Technology" DOI: 10.13052/jmbmit2245-456X.431

If accepted or submitted, state journal:

Has the article/manuscript previously been used in other PhD or doctoral dissertations?

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6. Finalization of the manuscript and submission	A

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Full name of the PhD student: Sriganesh Kamasamudra Rao

This declaration concerns the following article/manuscript:

Title:	Applications of CONASENSE
Authors:	Sriganesh K Rao, Ramjee Prasad

The article/manuscript is: Published ☒ Accepted ☐ Submitted ☐ In preparation ☐

If published, state full reference: Book Chapter "Applications of CONASENSE", River Publishers "Towards Future Technologies for Business Ecosystem Innovation" ISBN: 9788793609778; e-ISBN : 9788799923700

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Has the article/manuscript previously been used in other PhD or doctoral dissertations?

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2. Planning of the experiments/methodology design and development	A
3. Involvement in the experimental work/clinical studies/data collection	A
4. Interpretation of the results	A
5. Writing of the first draft of the manuscript	A
6. Finalization of the manuscript and submission	A

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Signature of the PhD student

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